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Details of the

Topics Discussed by Steel Men

at the Twenty-Second Annual Convention of the Association of Iron and Steel Electrical Engineers held last month at Chicago, Ill.

WORTH-WHILE accomplishments in the way of standardization and safety, coupled with a very successful Exposition marked the Twenty-Second Annual Convention of the Association of Iron & Steel Electrical Engineers at Chicago, June 7 to 11. On the first day of the convention the recommendations of the Safety Committee regarding the safe operation of cranes was discussed and unanimously adopted by those in attendance. The safety code and the discussion on it are given on page 299.

The second day was devoted to electric transportation, as this is a problem that will be confronting most steel plants in the very near future, if not at present. Abstracts of the papers on this subject are given on page 303. The subject of most interest to the membership on the third day was the report of the Standardization Committee relative to standardizing mill-type motors. The recommended standards for mill-type motors are given on this page.

On the fourth day the report of the Electric Heat Committee was presented, details of which are given on page 301.

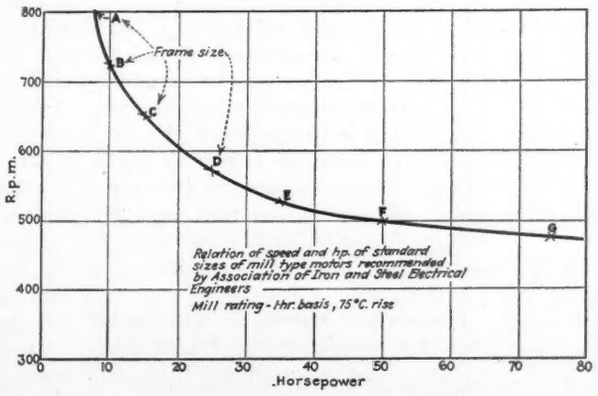
An unusually successful exposition of machinery used in the manufacture of iron and steel was held, 76 exhibitors showing products ranging from motors to air cleaners and from fire brick to electric industrial trucks, as well as control equipment, lubricating equipment, anti-friction bearings, switching equipment, electric heating devices, armature repair tools, storage batteries and lighting equipment.

In the following pages are given abstracts of the papers together with the discussions on them.

Standardization of Mill-Type Motors

By A. C. CUMMINS *Chairman, Standardization Committee, Electrical Engineer, Duquesne Works, Carnegie Steel Co.*

Due to the fact that a great deal of the work on standardization of mill-type motors was done shortly prior to the convention, Mr. Cummins was unable to present a formal paper, but spoke extemporaneously on the different points on which he and the committee had been able to reach an agreement. Mr. Cummins first outlined the steps which led to the calling of a standardization committee on this particular subject. Late last year he learned that one large manufacturer of mill-type motors contemplated bringing out a new line of these mill-type motors. Believing that this was an opportune time to effect standardization of mill-type motors, a committee was appointed and the first meeting was held at Duquesne Works, December 11th, 1925. First, letters were sent to the presidents of all the steel companies to ascertain if they favored such a step, and also to apprise them of the interest of steel mill electrical engineers in inventory reduction and consequent reduction in maintenance



Horsepower and speed of standard mill-type motors recommended by Association of Iron & Steel Electrical Engineers.

The points marked *A, B, C,* etc., refer to the frame sizes selected by the Standardization Committee. The curve shows the speed horsepower relation for the seven standard sizes selected. The data given by the curve is the mill rating on the 1-hr. basis with a temperature rise of 75 deg. C. More complete data is given in the table on page 298.

costs. The replies from the presidents of the various steel companies were very gratifying and were almost unanimous in approval of the steps contemplated by the Standardization Committee. However, the presidents of several steel corporations pointed out that the Standardization Committee should limit standardization to external features of the motor and the determination of standard horsepowers and speeds. They felt it was not the duty of the Association to go inside of the motor. In this connection, Mr. Cummins pointed out that it was not the attitude of the Association to ask the manufacturers of mill-type motors to immediately bring out a new line of motors to meet the recommended standards but rather to come to the standard of the Association as soon as they were able or desired to bring out a new line of motors.

Letters were then sent to the manufacturers of mill-type motors and also to some other manufacturers, asking that they send representatives to a meeting in which some attempt would be made at standardization. The first meeting was held in March, at which representatives were present from the Electro-Dynamic Company, the Allis-Chalmers Mfg. Co., Reliance Electric & Engineering Co., Crocker-Wheeler Electric Mfg. Co., Westinghouse Electric & Mfg. Co., and General Electric Co. Only the last three of these companies are manufacturers of mill-type motors, but the other three were sufficiently interested in standardization of motors (due to the possibility of their bringing out a mill-type motor in the future) to desire to have a part in the standardization program. In the meantime, letters had been sent to the membership of the Association, asking leading questions relative to the points on which standardization was desired, and also just what steps were favored and what were disapproved. Letters were sent to approximately 350 active members and some 160 replies were received.

The method of approach in the matter of standardization was to plot the various characteristics of the different mill-type motors now on the market and then strike an average between them, based on the experience and the desire of the Standardization Committee and the representatives of the different manufacturers. For instance, in determining the relation between the frame sizes and horsepower ratings, a graph was drawn with horsepower as abscissæ and frame size as ordinates. Curves were plotted for the General Electric type MD motors, the Crocker-Wheeler Type CW motors, and the Westinghouse type MC motors. A fourth curve was then drawn which averaged the conditions of the other three curves and at the same time represented what the committee and the manufacutrers thought would be desirable. It so happened that the curve for the standard motor fell nearest to the Crocker-Wheeler motor for this particular characteristic. Additional curves were then drawn for other motor characteristics; for instance, a curve was drawn showing the relation between speed and horsepower for the different frame sizes. In this case the recommended speed for the standard motor was higher than that of the type MC motor, but lower than for both the type MD and type CW motors. This was also true of the torque curve. The accompanying diagram shows the relation of speed and horsepower for the standard sizes of mill-type motors as recommended by the Standardization Committee. In this curve the motor is rated on the mill rating of a 1-hr. basis with a temperature rise of 75 deg. C. Other curves from which standard curves were made, showed the relation between frame size and speed, the relation between frame size and per cent increase in horsepower above previous size, and the relation between actual increase in horsepower between sizes and the frame size.

From these curves it was found that the present eleven frame sizes in use could be reduced to eight. Further investigations brought out the fact that one manufacturer sold only three per cent of his entire output of mill-type motors in the largest or 100-hp. size and therefore this size was also eliminated from the standardization program. In the accompanying table are given the characteristics for the seven standard frame sizes for both the mill rating and crane rating, listing horsepower and speed as well as torque. The standard sizes of anti-friction bearings for armature bearings and axle bearings, as well as the diameter of the armature shaft at the bearings, are also shown.

Characteristics of Recommended Standard Mill-Type Motors

Frame Size	Mill Rating			Crane Rating		Recommended Sizes of Anti-Friction Bearings			Diameter Armature Shaft at Bearing
	Hp.	Speed	Torque	Hp.	Torque	Armature Bearings	Axle Bearings		
A	7½	800	49	10	76	311	216	313	2.1654
B	10	725	72	13	109	311	218	315	2.1654
C	15	650	121	20	188	313	220	317	2.5591
D	25	575	228	33	350	316	222	319	3.1496
E	35	525	350	45	520	317	224	320	3.3465
F	50	500	525	65	795	319	226	321	3.7402
G	75	475	830	100	1,280	322	230	322	4.3307

The diameter of the jackshaft or axle bearings as recommended by the Committee range in size from 3½ in. to 5¾ in., depending on the rating of the motor. These sizes have been selected so that these shafts will have the same factor of safety as the other shafts ordinarily used on the driven equipment.

In attempting to standardize the different classes of motors, it was found that there were two fundamentals which determine the design. These are the height of the armature shaft above the bedplate, and the length between the armature bearing centers. Once an agreement has been reached on these two dimensions, it is not difficult to reconcile the remaining differences. In most cases the recommended standard heights for the different sizes of standard mill-type motors are slightly less than the height of the existing mill-type motors. The over-all length is approximately the same as on existing types. This results in getting a little more motor in the same space in the case of the new standard motor.

Standards were agreed upon for the face, diametral pitch, and general dimensions of the motor pinions for the different sizes of motors.

In determining the armature shaft sizes for the recommended standard motors, the diameters agreed on were slightly less than are customarily used on the first two sizes of motors, and all of the remaining sizes were increased in diameter. It was agreed to follow the standards of The Electric Power Club on key-

ways and tapers for the armature shaft.

In the questionnaire previously mentioned by Mr. Cummins, the question was raised as to whether or not anti-friction bearings should be accepted as standard for mill-type motors. Replies indicated that those who had extensive experience with anti-friction bearings strongly favored their adoption while the majority of the replies, based on numbers, indicated that motors equipped with sleeve as well as anti-friction bearings, would be in demand. Inasmuch as the majority voted for the sleeve-type bearings, the recommendations are for a motor equipped to take either sleeve or anti-friction bearings. Mr. Cummins pointed out that if an operator will standardize on anti-friction bearings, he will be able to decrease the over-all length of the motor; that is, the difference between the brake and the pinion will be from 2 to 5 in. less than would be the case if sleeve bearings were used. Mr. Cummins also stated that it was agreed by the committee that the anti-friction bearings used on armature shafts and axle shafts must be enclosed in dust-proof capsules which are clamped in the motor end frames or axle bearing supports, as the case may be. This was required because the armature and jack shafts may be exposed to mill dust on many occasions while lying in storage, and it was thought that adequate provision should be made to protect the anti-friction bearings from dust and dirt.

In discussing the report of the Standardization Committee, J. D. Wright of the Engineering Department of the General Electric Company stated that his company was contemplating bringing out a new line of mill-type motors and for this reason was very glad to co-operate to the fullest extent with the Standardization Committee. A. J. Standing, electrical superintendent, Saucon plant, Bethlehem Steel Company, expressed his pleasure regarding the splendid co-operation shown by the different manufacturers of mill-type motors. C. S. Proudfoot, General Manager, United States Ferro Alloys Corporation, stated that at first when he heard of the steps taken by the Standardization Committee, he was not in favor of the program. However, the results outlined by Mr. Cummins looked very promising and met with his full approval.

A. M. McCutcheon, Chief Engineer, Reliance Electric & Engineering Co., stated that should his company bring out a mill-type motor in the future, they would most certainly conform to the standards recommended by the Association. He felt that the standardization program set up by the Association should be held up as a model for future work along this line. He spoke of the difficulty that had been encountered in attempting to get an agreement on standardization of general-purpose motors, and which to this day has not been effected. He pointed out that there is no trouble in actually arriving at a set standard for general-purpose motors; the difficulty lies in getting the manufacturers to agree on a definite program.

Brent Wiley of the Westinghouse Electric & Mfg. Co., expressed his gratification at the co-operation and results that had been secured by the Standardization Committee.

D. M. Petty, Superintendent, Electrical Dept., Lehigh plant, Bethlehem Steel Company, moved that the work of the Standardization Committee be made an official part of the work of the Association. This motion was carried.

Rules for Safe Operation of Electric Overhead Traveling Cranes

The following recommendations were presented before a very enthusiastic and successful meeting of the Safety Division which followed a general luncheon given to all members of the Association at the opening session.

Rules for Crane Operators

(1) The operator should be examined by a foreman or someone designated in order that his familiarity with crane parts and their uses, as well as his ability to safely operate the crane, may be determined in practice and certified to by the examiner.

(2) The operator shall enter or leave his crane at the designated places, making use of the steps or ladder provided at those locations and having both hands free. All materials too large to be carried in pockets shall be raised and lowered by means of a hand line. The hand line must not be attached to the person of the operator.

(3) No one but the craneman shall be allowed in the cage except for repairs, inspection, or instruction of new men or for safety of men working on the crane runway.

(4) The operator shall keep his crane clean and free from all loose boards, tools, bolts, or other objects which may fall on men below or may cause tripping and falling of repairmen when working on the crane.

(5) The operator should inspect his crane at the beginning of the turn, or at least once each shift, and report at once any mechanical or electrical defects, especially noting the condition of cables, limit switches, signal gongs and collector shoes.

(6) The operator shall be responsible for the proper oiling and greasing of his crane and he should report any defects in the oiling system on any part of the crane.

(7) The operator, when about to handle material with his crane, shall devote his entire attention to his work and shall pay careful attention to the following points:

(*A*) Is the hitch of proper length and is it safe?

(*B*) Is the signal given by the proper party and does the operator understand the signal? If in doubt he must not operate.

(*C*) Can the load be carried without passing over the heads of men?

(*D*) Will load clear all obstacles?

(*E*) Test brakes by means of a short lift and return of controllers to "off" position.

(*F*) Allow no one to ride the hook or load.

(*G*) If craneman discovers men on crane runway, he should stop his crane until proper protection is provided.

(8) The operator shall avoid bumping other cranes on the runway, but if he is ordered to do so, he must move the crane slowly, with regard to the safety of men working on or below the idle crane.

(9) The operator must not make side pulls unless ordered to do so by a foreman.

(10) The operator must be sure that his controllers are in the off position and switch opened before leaving the crane, and in case of failure of power the controllers must be immediately set in the off position.

(11) In case a controller sticks the operator must pull the main switch at once.

(12) While repairs are being made to the crane, the operator must stay on the job and help with repairs. If ordered to remain in the cage, he must not operate any motion unless he is told that every one is safe.

(13) When the operator is inspecting, repairing, or lubricating his crane, the main switch must be locked in the off position.

(14) In case of a fire on the crane, the operator must use the fire extinguisher provided and must notify the foreman, who shall see that the

fire extinguisher is promptly refilled.

(15) An operator must not operate his crane if he is not physically fit to do so. He should report to his foreman at once.

(16) The operator must signify his understanding of these rules and must realize that they are intended to help him safeguard the lives of his fellowmen.

Rules for Floormen

(1) Foremen when signaling to the crane operator must use the approved crane signals and above all, they must be sure that they do not confuse the operator.

(2) Floormen must be responsible for all slings, chains and hooks and for their proper use in order to make safe hitches, bearing in mind the capacity of the slings and of the crane.

(3) Floormen shall be sure that the crane trolley is centered over the lift in order to prevent swinging of the load.

(4) Floormen must adjust the slings and chains so that they will not strike them on the ground when the crane is moving without a load.

(5) Floormen shall not ride the hook or load or permit others to do so.

(6) An extra man should be in the crane cage to warn the operator when men are working on the crane runway except where approved track torpedoes are used.

In recommending the adoption of these rules, A. J. Standing, Electrical Superintendent, Saucon Plant, Bethlehem Steel Company, stated that the 16 rules composing the code were boiled down from 52 rules that were submitted by the safety organizations of the various steel companies. It was felt that the rules should be as short as possible and few in number, so that they could be readily absorbed and made use of by the average craneman. The rules are general in nature and are not intended to be arbitrary. They are applicable to all plants and special rules should be added to them to fit special conditions in the various plants. Various modifications of the rules were suggested by different members, such as provision for audible signals, testing of limit switches, method of cleaning cranes, and also a rule requiring that all maintenance men should be off the crane whenever regular operation is resumed after a period of repair or maintenance. The general membership, however, felt that these were special rules and should be covered by the supplementary rules added to cover special conditions in a particular plant. The rules were adopted in the form submitted by the committee and presented in full in the foregoing pages.

At this same meeting several addresses were made regarding safety in connection with cranes. Dr. W. P. Fisk, Chief Surgeon and Physician of the International Harvester Company, spoke on, "Physical Qualifications of a Crane Operator." In brief, he put forth the following points: (1) The age of the crane operator should be such that he will avoid the indiscretions of youth and yet not be so old that he has begun to fail. He felt the age should be between 30 and 45. (2) The crane operator should speak the language of those with whom he works. (3) He felt that considerable should be known about the family history of the operator. For example, he would want to know if there were any peculiarities in his family, such as insanity, epilepsy, and the like, and also whether he was excitable, nervous, or inclined to drink. (4) He would make his selection of crane operators from those who had already proven themselves in some department of the works rather than endeavor to pick up his operator from the labor at the gate. He also felt that the crane operator should know more about electricity than the ordinary employee. (5) Dr. Fisk pointed out that a married man was more steady than a single man, and he would prefer this type for crane duty. (6) In regard to the physical examination to which he would subject crane operators, he brought out the following points: Weight and height have no bearing on the fitness of an operator. Vision and hearing are very important. He would not accept an operator without perfect vision and would test vision for both far vision as well as near vision. The crane operator must hear everything. He should be cool-headed and his general health should be good. He stated that high blood pressure is not a dangerous condition, provided it is accompanied by intervals of low pressure. He would also examine the condition of the craneman's heart with a view of ascertaining the possibility of collapse while on the job.

Charles B. Scott, President of the National Safety Council and Director of the Bureau of Safety serving the Insull properties, pointed out some of the work that the National Safety Council was doing and also how it was important that men engaged in safety work should keep abreast of the times and take advantage of every medium by which they could increase their knowledge on improved safety methods. He stated that co-operation is one of the most important problems confronting the safety men of today and pleaded for a co-operative interest in the National Safety Council.

As proof of the necessity for co-operation between the electrical engineer and the safety engineer he presented an analysis, made under his supervision, of some 12,000 accidents occurring during a period of several years among 50,000 employees. Of these accidents only 8 per cent were caused by electric current. However, this 8 per cent of the total accidents was responsible for 75 per cent of the total accident costs, for 75 per cent of the total lost time, and also for 75 per cent of the fatalities that occurred. Upon devoting marked attention to the 8 per cent of electrical accidents, he was able to reduce them considerably in less than one year's time.

Mr. Scott also pointed out that at least 70 per cent of the accidents that occur are due to the men who are engaged in the work. As a remedy for this, he advised first, careful selection of men who do the work; second, careful instruction to the men on how the work should be done; and third, careful and close supervision of the men. In most cases, it is the last of these factors which is overlooked and in his opinion the majority of accidents occur when this supervision is relaxed. Safety should be considered as a part of actual operation and until such is the case the rallies, posters and other propaganda do not have their full effect.

Views of opposite ends of one of the two exhibition halls used for the Iron & Steel Exposition at Chicago.

Exhibits in the second exhibition hall are shown on pages 302 and 304. A total of 76 manufacturers displayed their products at this exposition.

A. C. Cummins, Electrical Engineer, Duquesne Works, Carnegie Steel Company, pointed out some of the causes of electrical accidents that have occurred in his plant. The first cause was shocks. Many of these are due to the fact that many circuits cannot be completely isolated and killed when worked upon. New plants should be designed to take care of this point. Electric burns are due mostly to negligence and are caused by lack of instruction. A third class of accidents is due to equipment failures, such as limit switches.

In case obsolete electrical equipment is in use, improved equipment should be substituted. Two other causes of accidents are fires and explosions, which are very rare. A sixth cause of accident is lack of co-operation; his suggestion was that maintenance engineers should work hand-in-hand with the safety engineer.

Report of Electric Heat Committee

By W. P. CHANDLER, Jr., Chairman
Special Engineer, Carnegie Steel Co., Pittsburgh, Pa.

Arc Melting Furnaces—The use of arc melting furnaces in the steel industry has developed in two distinct branches: the production of ferro-alloy steels, and the steel foundry. In the case of the former, the ease with which the temperature, alloy additions, and slag compositions can be controlled, coupled with a much higher market price, allows the use of the high-priced fuel. However, except in some few special cases, large tonnage production of plain carbon steels in electric furnaces in competition with other fuel-fired furnaces, would not be very productive of dividends.

The use of the arc furnace in the steel foundry has been steadily growing. Judging from the new installations made and the continuance of existing installations in operation, the electric arc furnace is an economical furnace for the production of steel castings.

In the production of gray-iron castings it would appear as though the electric arc furnace would find its most fitting application. It is rapidly increasing in favor and has proven successful in every case that can be traced. Its adoption in this field allows one furnace to supply either iron or steel. It is possible to use scrap unsuitable for cupola practice, and at the same time reduce the cost per ton of castings by a very substantial amount.

The past 18 mos. have witnessed a renewal of interest in the possibilities of duplexing with the electric arc furnace. This year a contract has been let for the installation of a 25-ton furnace for duplexing on special steels from an open hearth for the making of ingots.

With the advent of more and more continuous molding and the introduction of permanent mold machines, there has risen a need for a more continuous supply of hot metal in quantities suitable to the output of these machines. Batch operation is usually unsuitable for these improved molding methods and various schemes of continuous pouring have been developed. In brief, they involve the maintaining of a constant bath of liquid metal with definite amounts of metal tapped at equal intervals and a like amount of cold scrap added immediately after each tap. Duplexing hot metal is particularly adaptable to schemes of operation which require a continuous delivery of metal to the pouring floor.

Induction Furnaces — The development of the induction furnace, and especially electrical equipment which will place an installation on an economical basis, offers great possibilities in the field of electrical heating. So far its development and application have been confined principally to the non-ferrous industry, the production of carbon-free ferrous alloys, and to experimental laboratory work.

Resistance Furnaces (High Temperature Applications) — In order that the various sources of economy may receive the proper consideration from any one contemplating an installation of high-temperature resistance furnaces the following list of points is taken from statements made by users of the equipment. Due to the differential, usually in favor of liquid or gaseous fuel as against electricity, the amount of gain to be derived from secondary sources usually determines whether an installation will be an economic success or not. The following are the points of advantage as experienced by users of such electrically heated equipment:

1. Repairs are less, due to the linings not being subjected to excessive temperatures.
2. Operating labor less per ton than in the case of solid fuel.
3. Time required for heating furnace up to working temperature is less.
4. Rejections less; in some cases this statement is not true.
5. Product more uniform, due to more accurate control of temperature.
6. Construction more adaptable to automatic operation.
7. Increased electric load factor makes cheaper electric power costs.
8. Furnaces used at off-hours given power at low price.
9. Cost of current less than cost of solid fuel. In a great many cases the actual fuel costs are found to be less with oil or gas than with electricity.
10. Scaling and decarbonizing may take place if great care is not exercised.
11. The comfort of the operators is much greater, where no fumes are experienced.

The small furnace, resistance type, is finding a considerable number of applications in tool rooms for heat-treating purposes throughout the steel and other industries. Especially when equipped with certain special types of control it is well adapted to this service. The question of cost of fuel for these small furnaces is usually only a secondary consideration for quality of product and ability to duplicate results is of prime importance.

The application of such furnaces to the pipe and tube industry for the treatment of threading tools and piercing points is only one of a great number of installations.

Low Temperature Applications—The application of resistance-type electric heating to low-temperature work is wide and various. New uses for such heating are appearing from time to time and, especially in plants which are considering complete electrification, applications of electric heating are considered which would not be economically sound, except in their relation to the whole scheme. Under such headings can be mentioned the production of process steam at distant points by using immersion heaters, the heating of small outlying office buildings, shops, etc. In other cases where the differential between electric heat and other fuels is not too great, the added advantages derived from the application of electric heat to certain processes show a gain from electrification. At the Maryland plant of this company an installation was made on an electrically heated tin pot. On the tin side, 100 kw. of heating units was installed, of which 75 kw. was automatically controlled. In the beginning 25 kw. capacity of heating units was installed on the

palm oil side but it was found later that its use was unnecessary except for a short time for starting the pot. The installation was made late in December, 1925, and the operating results so far indicate that from a tinning standpoint the results are better than with gas-fired pots. Production has been increased about 50 per cent per pot and the sum of the other factors entering into operation has been reduced materially, so that the additional cost of electric heat over gas has been offset, showing slight savings in favor of the electric pot.

The application of electric heating to furnaces for drying and annealing wire and similar products is growing in favor. One such installation is used for drying acid from rods before drawing at the National Screw & Tack Co., Cleveland. Natural gas had been used previously as fuel. The electric-heated furnaces were found to have much greater capacity, three electric ovens replacing seven gas-fired ones. The capacity of the ovens has increased from 1.5 tons per hour to 5.5 tons per hour per oven. A secondary advantage obtained was the elimination of the glazed coat left on the rods dried in the gas furnace. The coating scratched the rods and clogged the dies, and its elimination in the electrically-heated oven has resulted in longer life for the dies. The cost of electric heat is greater than for gas but the increased tonnage has resulted in a lower cost per ton.

An interesting application of electric heat equipment to a galvanizing kettle was placed in successful operation early in 1925. As far as is known this is the only electric galvanizing kettle in existence. The operators of this kettle report that in comparison to the previously used coke kettle, the operation is cheaper and drossing is reduced to a negligible amount. The production has been increased, working conditions are better and because of the automatic control no attention is required.

One class of repair work which often causes trouble in a steel mill is the rebabbitting of bearings. The class of labor often employed in this work is not of the best so that accurate control of gas-fired furnaces is not obtained. The results under such circumstances can hardly be much better than they are. The installation of electrically heated pots at one steel mill has been proven economical and very satisfactory. A much better product and much greater capacity is being obtained from the same crew of men with no increase in the fuel bill.

In one shop four 1,500-lb. soft melting pots are used on large railway motor bearings and axle shaft shells. Each pot is controlled by a pyrometer, set according to the particular composition being poured. One pot is used only for tinning purposes. Tin-base babbitt is for the most part used on railway bearings because of the severe service conditions.

This installation has been in practically continuous operation since September, 1924, and has been shown to many visitors interested in this particular class of work. The operators are very pleased since changing from gas-fired pots. They give the reasons as: Better working conditions through elimination of fumes and lower temperature radiated from the pots, as well as marked improvement in the quality and texture of the bearings produced, because the temperature is controlled within a few degrees of the correct pouring temperature for the alloy. The watchman starts the pots at 5:00 a.m., which brings them up to the correct temperature by 7:00 a.m. The total installed capacity is 100 kw. operating at 220 volts.

Electric Arc Welding in the Steel Industry—Electric arc welding provides a satisfactory means of welding without preheating, and in many cases renewal of parts made of grey iron. Work that has been done in this direction includes repair of blowing engine cylinders which have cracked in service, large gas engine cylinders which operate on blast furnace or producer gas, crane engine cylinders, locomotive engine cylinders, pump cylinders, steam separators and steam traps. The saving in work done by the electric arc welding process on material of this kind is usually very large. Spare castings are usually not carried for parts of this nature and a delay of one to six weeks occurs between the time the casting is ordered and the time it arrives on the job. In many cases a machining operation to get the casting ready to use also causes considerable delay. Welding with the electric arc in place of caulking is an important application in steel plant work. Jobs of this nature are found on gas lines carrying producer gas or blast furnace gas, on blast lines, on the blast furnace shell itself and on stoves. After riveted plate construction, such as the above, has been in service a while the riveted joints become loose and a considerable amount of leaking results. In order to redrive the rivets, it is necessary to practically tear down the structure. Welding on this work has been found to cost slightly less than caulking with an air gun.

Electric arc welding finds a wide field of usefulness in the repair of broken and worn steel castings.

Under this classification come yokes, truck frames, trunnions and cinder ladles, hot metal ladles, ingot buggies, steel castings on gas producers and stoves, electric cranes, trucks, and manipulator castings.

Electrically welded stacks for the open-hearth, sheet mill, and miscellaneous smoke stacks about the mill, are better and last longer than ordinary riveted stacks.

Steam lines around a steel mill are a source of considerable amount of waste and may be a cause of shutdown. The large steam lines have cast steel flanges screwed on the pipe. It is the practice of several plants within the writer's experience to electrically weld the cast steel flange to the pipe, in addition to the threading. It appears that the threaded joints eventually leak and the wire drawing of the steam and corrosive action weaken the pipe at the thread, causing waste and liability of failure of the steam line, with attendant loss of life and shutdown of the plant. This is another case of insurance against shutdown by the use of electric welding.

Every steel mill has a large number of crane motors and there is an extensive application of electric welding in building up the bearing area of the armature shaft, the pinion seats and straightening out keyways which have been damaged. This work falls in the electric welding field due to the economical application of metal through the use of electric arc equipment.

There is a considerable time saving in the use of electric welding for the above purposes, and there is a saving due to the fact that a new shaft does not have to be machined for the job. The elimination of pressing the old shaft out and new one in, is also an important item.

It is quite pleasing to note the distinct advance welding equipment manufacturers have made in the line of stable arc equipment. The arc characteristics alone many times spell the difference between a failure and a successful weld. Realizing the importance of good equipment, good materials and operators, electric arc welding is the most powerful and increasingly useful tool a maintenance superintendent has.

When properly selected, organized and instructed, welding operators will do good, conscientious work, and will do justice to electric arc welding, but let the operator be dissatisfied, untaught and trying to "get by," nothing can be hoped for. So it is, then, of the utmost importance to have specially selected men taught to handle the electric arc by an expert in welding.

Use of Electric Industrial Trucks and Tractors in Iron and Steel Industry

By HAROLD J. PAYNE
The Society for Electric Development

If we analyze the possibilities for continuing to cut production costs in various branches of industry, we find that it is very often in improvement of transportation methods that the most promising possibilities exist for savings. This may be partially accounted for on the basis of two facts: (1) That in the past, gaps not capable of being filled by heavy, high-capacity equipment have not received their fair proportion of attention and, (2), that up to the time when the cost of labor began to soar, boards of directors were inclined to favor appropriations for major changes in process equipment rather than relatively insignificant budgets for patching up the leaks in faulty transportation operations, when recommendations were made regarding savings that could be obtained.

The electrical industrial truck and the tractor represent one of many types of equipment for meeting materials handling problems effectively.

The industrial truck is being successfully applied to transportation problems in the older types of blast furnaces. The quantity of material handled at a modern blast furnace is very large. A furnace turning out 400 tons will have to be fed every 24 hr. with approximately 800 tons of ore, 400 tons of coke and 200 tons of limestone, or a total of 1,400 tons of solid materials.

From the material handling standpoint there are three types of furnaces: (*a*) hand-filled elevator furnaces; (*b*) skip-filled furnaces without larry car equipment and, (*c*), skip-filled furnaces with larry car equipment. At the first two types of furnaces, industrial trucks may be used to advantage in speeding up the charging, reducing the labor expense, and relieving a shortage in a very specialized type of labor.

In the earlier types of elevator furnaces the charges are handled in two-wheel buggies. These buggies are pushed from the storage bins to the elevator at the furnace and then lifted to the charging stage, where two men empty them into the charging bell. One of these buggies loaded with ore weighs from 1,400 to 1,600 lb. and the man who pushes this load comes under the heading of selective labor. He is especially trained for this very heavy work and his muscles have become hardened to it. This class of labor is very scarce and it is very difficult to break in new men.

Among others, five furnaces of the Carnegie Steel Company have been equipped with trucks and a brief description of the work being done will supply useful data for working out similiar problems. At the time it was equipped, furnace No. 2, at Bellaire, was of the hand-filled type first mentioned. Between the wheels of each of the old buggies, a sub-frame made of angle iron was built. This frame was placed about 12 in. from the ground, allowing sufficient clearance for handling with a standard elevating platform truck. The buggies were picked up at the elevator, carried to the ore pocket and returned to the elevator. When hand buggies were carried by the elevating platform trucks, however, a total of six trucks with 13 operators is said to have replaced 54 specialized laborers.

The rebuilding of open hearth furnaces, an operation usually necessary annually or oftener, involves handling 300 tons of refractories for a 50-ton furnace. In many plants brick are now wheeled from car or storage to the furnace, thus involving a large amount of unnecessary handling. Lift trucks handling brick on skids in the plants where they are made are earning $8,000 to $12,000 a year over hand wheeling costs, and it is our belief that a corresponding saving is possible in open hearth plants where a large number of furnaces is operated.

One of the most profitable uses to which the industrial truck has been put in the steel industry is the handling of rods and flat strip, including band and hoop stock. Several plants are using ram or crane trucks

for this purpose, while others use tractors with trailers or lift trucks with skids. The final choice of equipment depends quite largely on individual plant conditions.

The difficulties involved in handling these materials are generally appreciated. A prime consideration involved in the selection of equipment for this work is flexibility. Wire as it comes hot from the mill is heavy, bulky and awkward to handle thus making it necessary to meet a set of special conditions.

The crane truck has been found by several users to be well fitted for unloading, as well as for loading cars or other vehicles with rods or wire. A large manufacturer of nails, rivets, etc., found that such a machine saved 80 per cent over the cost involved in handling wire manually. Formerly it was the custom to handle bundles of wire weighing 150 lb., but with the aid of mechanical equipment of this kind, it was found possible to handle 300-lb. bundles without difficulty. Consequently, every department in the plant has been affected.

Handling of pipe fittings and small iron or steel sundries is occasionally improved by the use of a magnet sling from a crane attached either to a low-lift or straight platform truck. Power is supplied from the battery of the truck and the magnet is used for loading or unloading as is commonly the case, on a larger scale, in handling pig iron.

The storing of cases and kegs in warehouses, prior to shipment, constitutes an operation that is wide open to lost motion. The tiering truck, however, has come into favor in many plants for doing this work. The Bethlehem Steel Co., for instance, is reported to be using seven machines in its storerooms at the Bethlehem plant. Carrying its load of 2 or 3 tons to heights of 8 ft., this machine, having all of the flexibility of an ordinary low-lift truck, is often able to make large earnings. From eight to ten men per unit appears to be average experience with this type of equipment in warehousing.

The handling of black sheet, plate, etc., has perhaps received more attention on the part of manufacturers of electric truck equipment than any other series of operations in this industry. For some jobs, where the sheets are large, the elevating platform truck with skids is used; on others the tractor-trailer method has worked out satisfactorily; on at least one job the crane truck with a special cradle attachment is used for handling. When tinplate is the commodity to be transported, several specially-designed trucks become available, two of which have been designed particularly for handling this commodity.

Some time ago a survey was made to ascertain the average cost of handling tinplate, with hand trucks, at hourly or piece rates, manually as against handling with a fork-type truck. These figures are on the basis of 100 base boxes.

	Hand Trucks	Power Trucks
Handling loose tinplate in and about plants.....	14-16c.	4½c.
Handling loose tinplate from plant to car or vice versa	16-19c.	8½c.
Handling boxed tinplate in and about plants.....	12-14c.	4½c.
Handling boxed tinplate in and out of cars.....	15-17c.	8½c.

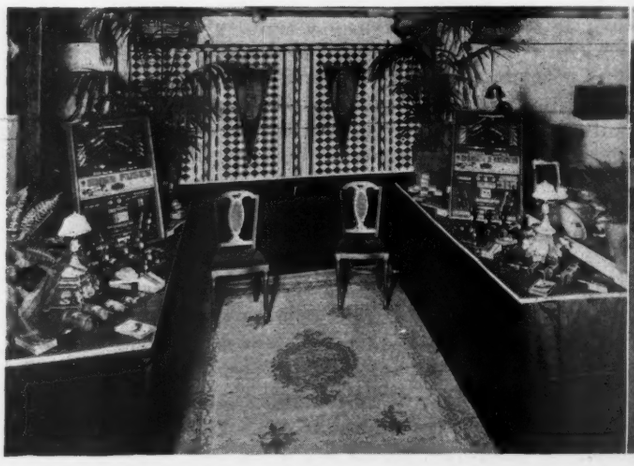
This same survey points out that definite possibilities exist for lowering the per ton cost of packing; this could be decreased as much as 50 cents per ton by replacing the average 1¾ base box holding 175 lb. with a box of the same sheet size to hold a ton. Should this idea prove sound and be generally adopted, with 1,400,000 tons of tinplate produced annually, a cut of $700,000 from this source is not at all impossible.

Throughout this account references have been made to savings in terms of men per unit or in terms of net earnings. One company that builds electric industrial trucks surveyed 15 plants in the Pittsburgh district about three years ago—plants that use one or two electric units and found the following averages to hold:

Maximum saving in per cent per plant	79
Average saving in per cent per plant	52
Maximum number of men saved per plant	18
Average number of men saved per plant	7½
Maximum saving per year on investment	345
Average saving per year on investment	270
Maximum saving in per cent per unit	75
Average saving in per cent per unit	29

It has been difficult to isolate average total fixed charges per unit, in various operations, but the most reliable figures obtained show that even in heavy service this charge rarely exceeds 60 cents per hour and that 50 cents is a reasonable average on all installations except those in which unusually difficult operating conditions have to be met.

In concluding this summary of the industrial electric truck applications in your industry, a few unusual applications of the equipment should be pointed out. The crane truck has proven especially valuable in the service of maintenance departments—each unit saving 35 men in one plant. Pipe laying was expedited in a Pittsburgh steel plant through the use of such a unit. At another plant a basket in which the electrician works while trimming arc lights is handled by a crane truck. A high-lift truck equipped with a plow has proved a valuable means of clearing narrow runways of snow in winter. Smaller plants use the electric industrial truck to spot freight cars in the absence of a locomotive. Heat-treating plants substitute long forks for a straight platform on the high-lift truck and decrease the labor required



for charging carbonizing furnaces by 15 men per unit employed.

The advantages gained through the application of this or any other equipment designed for similar purposes depends not only upon direct saving in payroll expense but also, to a very large extent, upon other factors. An automobile manufacturer increased production more than five times in a manufacturing area that was increased only 33 per cent and with a decrease in storage area of 25 per cent. A very large concern building agricultural implements has stated that one of the principle savings made comes from decreased inventory costs through keeping material in platform containers at all times. Many plants have experienced a decrease in labor turnover as a consequence of the substitution of labor-aiding electrics for back-breaking hand trucks.

Yard Switching and Mill Transportation

By W. B. POTTER and G. H. SHAPTER
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Yard switching is characterized by short movements and with considerable time lost for coupling and at switches. From observed operations the time in motion may be assumed as one-half to one-third of the time in service. While the maximum speed may be 10 miles an hour or more, the average speed is much less and the schedule speed will usually be found around 3 miles per hour, or about one-half the 6 miles per hour which is the conventional schedule commonly assumed.

The average power requirement for yard switching is considerably less than is sometimes appreciated. While the tractive requirements are high the schedule speed is so low that the average power used in performing the schedule may range from 30 to 60 kw. The maximum and average power while in motion will be considerably higher than these figures, depending upon the acceleration.

The steam locomotive is so generally used and has been so successful in switching service that there should be some good reason for considering other types of motive power. Expediting the switching movements, more hours available for service, lesser number of locomotives needed, lower maintenance, reduction in cost of fuel and the elimination of smoke, are some of the reasons which justify this consideration.

The Diesel or oil-electric locomotive is a comparatively new type of motive power, as regards its application to regular service. In effect, it is an electric locomotive deriving its power from an oil engine located in the cab, instead of from a trolley wire or third rail.

Freight yard switching is being successfully handled with 60-ton locomotives equipped with 300-hp. engines. Although 300 hp. is considerably less than the power rating of steam locomotives used in this kind of switching, it appears that these oil-electric locomotives handle the switching more expeditiously than do the steam locomotives having equal weight on the drivers.

The relative fuel consumption of oil-electric and steam locomotives in switching service can perhaps best be given by comparing the gallons of oil with the tons of coal. The records obtained indicate that 20 to 25 gal. of oil are equivalent to a ton of coal, so that with oil at 5 cents a gallon, the comparative cost of fuel on this basis would balance at $1 to $1.25 per ton for coal.

The gas-electric locomotive is similar to the oil-electric except as to the type of engine and character of fuel. The electric drive is advantageous with the gas-electric for the same reasons mentioned for the oil-electric. This locomotive is somewhat less expensive because of the lower cost of the power plant equipment, but the fuel expense is increased because of its higher cost per gallon and the lower fuel economy of the gasoline engine. The quantity of fuel for a given service will be from one-half to two-thirds more than for an oil engine, which with the ratio of 3 to 1 for the relative cost per gallon means a difference in fuel cost of about 5 to 1.

The storage battery locomotive with engine auxiliary is a combination in which a gasoline or oil engine, of sufficient power to provide the average demand, maintains the charge in the battery. The battery serves as a reservoir of energy delivering power at intervals whenever the demand exceeds the output of the engine. The power supplied by the engine further permits a reduction in the amount of battery required. There are places where the storage battery locomotive will best serve the purpose, but where it may be inconvenient to take it out of service for the purpose of charging.

The storage-battery locomotive may well be regarded as the best of the station-charged units. It is fully capable of handling yard switching and is as responsive to the demand as any electric motor locomotive. Its duty cycle is necessarily limited, however, to the amount of battery provided. Where the battery is adequate the performance is very satisfactory, but like all station-charged locomotives it must receive more energy than it delivers. Including the losses in the charging equipment usually required, the overall electrical efficiency will not be far from 55 per cent.

The electric locomotive is unquestionably the most powerful type of locomotive that may be used, and is the most effective of all to expedite switching movements. Its tractive power is limited, as in all cases, by the weight on the drivers, but the speed at which this tractive power may be obtained is only a question of motor capacity. These locomotives require a contact system throughout their range of operation and a power supply of suitable voltage. Either an overhead trolley construction or third rail may be used with equal success, so far as delivering the power is concerned.

The electric locomotive with storage battery auxiliary provides a means for entering upon certain tracks, as within buildings, where a trolley or third rail would not be permissible. The storage battery receives its charge while the locomotive is taking its power from the trolley, and so is in condition to supply power whenever it is needed. A comparatively small battery will usually be sufficient for this purpose.

Following is a brief description of some of the more common applications for electric and storage-battery locomotives in steel mill service.

The by-product coke oven is a comparatively recent development which includes all the operations through which coal goes when introduced into the ovens until it is finally placed on the cooling wharf.

An electric locomotive is particularly well suited to meet the special requirements for handling this coke. The usual type of coke oven locomotive is a 20-ton single truck machine especially designed with respect to the location of the operator. The operator is in an elevated cab where he has a clear view of all the operations which this locomotive must perform.

One of the most important of steel mill switching operations is the handling of hot metal in ladle cars from blast furnaces to Bessemer converters, mixers, or open hearth furnaces. The use of electric locomotives for handling ladle cars involves special consideration of the method of supplying power to the locomotives. Tracks run into the building underneath furnaces and over numerous crossings, so that it is practically necessary to design some special form of collector trolley device. Third rail shoes must be located far enough away from the main track to clear the casting bodies of the ladle cars. In spite of these handicaps numerous installations have been made. Some kind of self-contained locomotive is seemingly best adapted to the handling of hot-metal ladle cars, except when it is possible to provide a means of contact which is not too elaborate and expensive.

The handling of materials for open hearth furnaces is another very important operation in the steel mill. It is desirable to use a storage battery for this work because the tracks are usually inside of the building for at least 800 or 900 ft. in front of the ovens.

Many open hearth furnace buildings are so located that the scrap material must be handled up relatively heavy grades and around sharp curves before trains can reach the furnace floor. In general 20- to 25-ton locomotives would be the most suitable units for this duty. Cars for open hearth work are usually very crude in design and bearings are difficult to lubricate, so that car friction is quite high. It is likely that a combination trolley or third rail and battery locomotive would be found most suitable from an electrical point of view for this class of work. With the battery unit it would be possible to enter the building on the charging floor without the use of trolley wires or third rails. It would also be possible to operate the locomotive at the scrap pile without the use of third rails.

Economics of Steel Plant Railroad Electrification

By O. NEEDHAM and DAVID C. HERSHBERGER
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For the purposes of this study, we have assumed a typical steel plant having a narrow gage containing 9 miles of track, and a standard gage comprising 40 miles of track. The narrow gage railroad system is distributed around the open hearth furnaces and the mills in close proximity to the buildings, and is confined to a relatively small area and trackage.

This system employs small steam locomotives at present, and these in relatively large numbers considering the work to be done. The standard gage railroad system is also distributed throughout the plant, taking care of the transportation involving the use of standard railroad cars, ladle and slag cars, etc. The tracks comprising the standard gage systems are mostly located on the outer sections of the mill area, with many branches running into the various mills and by the open hearth buildings. The character of the work performed is diversified, but all of it comes under the class of switching service.

This study is confined to the two most promising systems of electrification for steel mill yard work. These two systems are as follows:

(1) The 250-volt, direct-current, third-rail system.

(2) The Diesel-electric locomotive.

It is generally recognized that certain sections of a narrow gage railroad system cannot be equipped with a third rail. One of these locations is in the open hearth pit where it is difficult to maintain the present track rails on account of the great weight they are subjected to at times in supporting the ladles and masses of steel resulting from clearing the ladles of "skulls" and sometimes from the relatively large masses of steel resulting from defective pouring. Under these conditions the installation of a third rail, which is located higher than the running rails, is impracticable. Another location is in the open hearth scrap yards, where steel is being transferred from standard gage cars to narrow gage cars. On the other hand, there are many sections of the narrow gage system which may easily be equipped with third rail construction. It is evident, then, that combination locomotives are required for part of the work, while other sections of the system can be served with ordinary third rail locomotives.

The combination locomotive should be a combination third rail and storage-battery type locomotive. It is preferable to make the transition from third rail to self-propulsion when going to sections of the track not having third rail, with minimum effort and manipulation of control. It is estimated that the following narrow gage electric locomotives would be required to replace the 21 narrow gage steam engines now in service:

5—50-ton combination third rail and battery-type locomotives.
5—25-ton combination third rail and battery-type locomotives.
6—25-ton third rail type locomotives without battery.

Past experience in steam railroad electrification and in the electrification of steam railroad terminals justifies a material reduction in the number of locomotives.

Experience has shown that an electric locomotive with a given weight on the drivers can do more work than a steam locomotive having the same weight on the drivers or, conversely, a given steam locomotive can be successfully replaced by an electric locomotive having less weight on the drivers. This is because the motors of an electric locomotive give a uniform tractive effort, whereas the cylinders of the steam locomotive provide a variable tractive effort. This uniform tractive effort minimizes the tendency to slip the wheels on the rails when accelerating heavy loads.

The following standard gage electric locomotives are required to replace the 15 standard gage steam locomotives now in use.

8—45-ton third-rail type locomotives.
4—80-ton third-rail type locomotives.

Upon first thought it would appear that the Diesel-electric locomotives should make a very favorable showing in steel mill yard service. So far as its performance is concerned, the

locomotive is well adapted for this service, but on account of the relatively high investment costs there is not so promising an outlook for the Diesel electric as for the third-rail type of locomotive, as will later be shown in this paper.

This type of locomotive may be put in service where the steam locomotives are now operating, without the necessity of erecting a third rail and, furthermore, may be placed in service a few at a time.

It is estimated that the following Diesel-electric locomotives would be required to replace the 21 narrow gage steam engines.

12—25-ton, Diesel-electric locomotives.
5—50-ton, Diesel-electric locomotives.

The following Diesel-electric locomotives are estimated as being required to replace the 15 standard gage steam locomotives.

9—50-ton, Diesel-electric locomotives.
4—80-ton, Diesel-electric locomotives.

In the accompanying table are given comparative operating and investment costs for displacing present steam locomotives by third rail or Diesel-electric locomotives.

The return on the investment shown in the table on this page is the minimum to be expected.

A comparative study of transportation systems for new steel plants places electric operation in even better position than where steam locomotives are now in operation. This is brought about by the fact that new steam locomotives are more expensive and carry a higher total fixed charge than do old engines. The result is that the return on the investment is very satisfactory as shown in the table and justifies electric operation as compared to steam.

The tables included in this paper show the worst conditions and give the minimum return that can be expected from electrification. There are a number of possibilities that could be taken into account that would improve the savings shown by either the 250-volt third rail locomotive or the Diesel-electric.

The 250-volt, direct-current system, employing third-rail type locomotives, is the most economical system of transportation for steel plant yards. The return on the investment, as compared with steam operation, is excellent and fully justifies the displacement of steam by electric motive power. A number of partial installations of this type are in operation with excellent results.

The Diesel-electric locomotive occupies second place in point of operating economy and return on investment as compared with third rail locomotives. The future of this type of locomotive is very promising and an extensive application of this type of motive power is anticipated.

New steel plants should employ electric motive power from the beginning rather than start with steam with the idea of changing over to electric later. The difference in investment costs is so quickly eliminated by the economies of electric operation as to leave no doubt as to the course to be pursued.

The steel plants cannot afford to continue to purchase new steam locomotives to replace worn-out units. The change-over to electric operation can be made in sections and a progressive program of electrification put through without heavy expenditures at any one time.

The working conditions would be improved by the elimination of smoke, dirt, and noise from the operation of steam engines.

The electric locomotive, receiving its power from a conductor, is the most reliable unit of motive power in existence. This has been fairly demonstrated in a large number of electrifications, some of which have been operating from 20 to 30 years. The third rail type locomotive has desirable features of operation that will be difficult for other types to equal. It is quickly made ready for service and its power is not limited by any local power plant or the locomotive itself for the reason that it has the steel plant power system behind it. It can handle heavy loads at moderate speeds and its general performance recommends it over other types of locomotives when a suitable conductor system can be installed.

Finally, it may be accepted without doubt that the complete electrification of steel plant yards would result not only in very large economies of a direct nature, but also in indirect benefits which cannot be evaluated.

In discussing the paper on "Economies of Steel Plant Railroad Electrification," W. P. Potter, Chief Engineer, Railway Dept., General Electric Co., said that Mr. Needham was conservative in determining the number of electric locomotives required to replace a given number of steam locomotives now in service. Mr. Potter felt that only 80 per cent of the number of electric locomotives mentioned in Mr. Needham's estimate would be actually required, thereby greatly increasing the return in favor of the electric locomotive as compared to the steam locomotive.

Considerable interest was expressed in the oil-electric locomotive by R. S. Shoemaker, Superintendent of Electrical and Mechanical Depts., American Rolling Mill Co. He believed, however, that an oil cost of 5 cents per gallon was lower than could be obtained at most steel plants. Mr. Hershberger of the Engineering Dept., Westinghouse Electric & Mfg. Co., replied that in the paper presented jointly by Mr. Needham and himself, an oil cost of 6½ cents per gallon had been used as being more representative of oil costs at the majority of steel plants.

Comparative Operating and Investment Costs for Steam, Third-Rail and Diesel-Electric Locomotives

When Displacing Present Old Steam Locomotives

	Third Rail Locomotives	Diesel Electric Locomotives	Present Steam Locomotives
Operating cost	403,155	437,450	786,900
Fixed charges	179,500	277,800	7,650
Total annual charge	582,655	715,250	794,550
Yearly saving over steam	211,895	79,300	.....
Net investment	1,298,700	1,821,000	382,000
Per cent return on net investment	16.3	4.35	.....

Comparison with New Steam Locomotives

	Third Rail Locomotives	Diesel Electric Locomotives	New Steam Locomotives
Operating cost	$403,155	$437,450	$786,900
Fixed charges	179,500	277,800	116,800
Total annual charges	582,655	715,250	903,700
Yearly saving over steam	321,045	188,450	.....
Investment	1,329,700	1,852,000	777,600
Per cent saving on investment	24.2	10.1	.....

Some reasons why

Low Power Factor Causes Trouble and Expense

in industrial plants, with a discussion of the causes for it, methods of measurement, and effect on charges made for electrical energy.

THIS IS the first of a series of articles in which the practical problems that revolve around the power factor of the distribution system in an industrial plant will be discussed. In this article Mr. Holston tells in a simple and understandable way what power factor is, shows why low power factor is undesirable from an operating standpoint, and discusses the relation of power factor to the price that the consumer pays for the electrical energy he uses. In succeeding articles that will appear in later issues of *Industrial Engineer*, methods of improving power factor, both with and without the use of special equipment designed for that purpose, will be described.

By JAMES B. HOLSTON

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POWER factor is a much talked of "will-o'-the-wisp" about which there are many misconceptions and a rather widespread lack of accurate information. Many power companies base their rates upon power factor, but the reasons why they penalize customers who have a low power factor and give a bonus to those who maintain a high power factor may not be entirely clear.

In the case of industrial plants that maintain their own generating equipment, the engineers frequently take the stand that low power factor causes no bad effects and need not be considered. Further information in regard to power factor—regardless of whether the electrical energy used is purchased or generated—may clear up some misunderstandings and help to shed some light upon this phase of power use.

Probably the most satisfactory way to explain the term "power factor" is to carry through the analogy of electricity and its manner of operation in a distribution system to the flow of a fluid in a system of piping. The following simile has been used, in part, by R. H. Rawll in Power Factor Booklet, published by the Electrical Apparatus Co., London, England.

Power stations are erected to force or pump this fluid to the consumer's premises and, if the switches are closed, it will flow through the various connected appliances, giving up its energy in the form of mechanical power, light, heat, and so on. After the electricity (as the fluid will now be called) has done its work it returns to the power house, just as in a hydraulic plant, after the water has passed through the power presses, rams, or other equipment, it flows back to the force pumps, where it is again sent out with renewed pressure. Now, in order to operate electrical machinery in a distant factory, a certain call for electricity is made on the power house and cables are laid to convey this current. But some electrical apparatus, especially induction motors, has the unfortunate knack of utilizing only a certain proportion, say 0.80, of the current flowing through it. Such an installation would have a power factor of 0.80 or 80 per cent. *It must be understood that this does not mean that 80 per cent of the power supplied is being usefully employed, while the remainder goes to waste.* Exactly the same amount of current returns to the power house as left it on the outward journey, 80 per cent of it having given up its energy and the remaining 20 per cent returning unused.

The greater the amount of current to be transmitted, the larger must be the cable through which it flows, just as in a water supply system the greater the amount of water required to flow through a pipe the larger must be the diameter thereof. This means that a cable of larger size would have to be put down to supply a consumer having low or bad power factor—with a large amount of "idle" current flowing—than would be necessary if the power factor was high or good; that is, with very little idle current present in the cables.

The detrimental effects of bad power factor are not confined to the cable systems, but may also be noticed in the generating equipment at the power house. An electric generator capable of turning out 5,000 hp. can deliver only 4,000 hp. when connected to a load having a power factor of 80 per cent, 20 per cent of the current being idle and being returned to the power house, having done no work. Consequently, larger generators have to be installed, with their attendant larger overhead charges, if the power factor is bad.

Thus it is seen that if the power factor—which may now be defined as the *ratio of useful current to the total current flowing*—of a system is raised, the following economies are effected, by the power company if power is purchased, and by the consumer if it is generated:

(1) Smaller cables and switchgear can be installed for a given load or, conversely, more consumers can be supplied by or more equipment can be connected to, a given cable.

(2) Owing to the decreased amount of current flowing in the cables the "electrical friction" or transmission losses are reduced.

(3) Less generating equipment with its necessary switchboard connections and attendance is required for a given load; therefore, there is less capital expenditure required.

(4) Each generating set can be run under such conditions that it will deliver its maximum output of power, at maximum efficiency.

There is also a considerable advantage from the technical point of view, in that when the power factor is high the absence of a large amount of idle current doing no work in the system renders the control of such a system much easier. High power factor and good voltage regulation go hand in hand, as well as do low power factor and poor voltage regulation.

Thus, it is seen that in the case

of two consumers on the lines of a central station, each using the same amount of power, the one whose system operates at low power factor is actually costing the power company far more than does the customer with the higher power factor; therefore, in common fairness they should be charged for power on a scale that varies with the power factors of their respective systems.

Reliable estimates place the amount of capital tied up in central station equipment in this country on account of low power factor at a figure approximately equal to the gross annual revenue. In 1924 this revenue was in the neighborhood of $1,350,000,000 and was derived from $6,600,000,000 of capital invested. This fact may explain the increasing interest of operating companies in power factor correction. Of course, if this tremendous investment is released, or even part of it, the result will eventually be a lowering of power rates.

Two important considerations that affect the power factor question from the standpoint of the consumer, regardless of whether power is purchased or generated in his own plant, are transmission losses and voltage regulation. With low power factor the transmission losses are excessive and the regulation is poor. Both of these factors add to the cost of power, for transmission losses show directly on the kilowatt-hour meter and poor voltage regulation causes reduced efficiency on the part of all other electrical equipment in the plant, therefore showing up indirectly in increased cost of power.

Transmission losses vary directly with the square of the current flowing; the total current is inversely proportional to the power factor. Hence, the losses vary inversely as the power factor squared. With 3 per cent loss at 100 per cent power factor the loss at 70 cent power factor is 6.1 per cent, and is 12 per cent at 50 per cent power factor.

A reduction of only 10 per cent in voltage on an induction motor may result in an efficiency of several points below that for rated voltage. Furthermore, power is a function of the product of voltage and current and for the same power as at full voltage a reduction in voltage means an increase in current, with a resulting increase in transmission losses. The "slip" of induction motors, which is the percentage by which the actual speed of the motors falls below the theoretical speed, increases with reduced voltage and where the motors are used to drive machines requiring constant and maintained speeds this reduction of voltage may prove serious.

These two factors deserve careful consideration in laying out any electrical distribution system. If it is practicable to do so, power factor correcting equipment should be installed on each of the various feeders to reduce transmission losses and improve voltage regulation thereon.

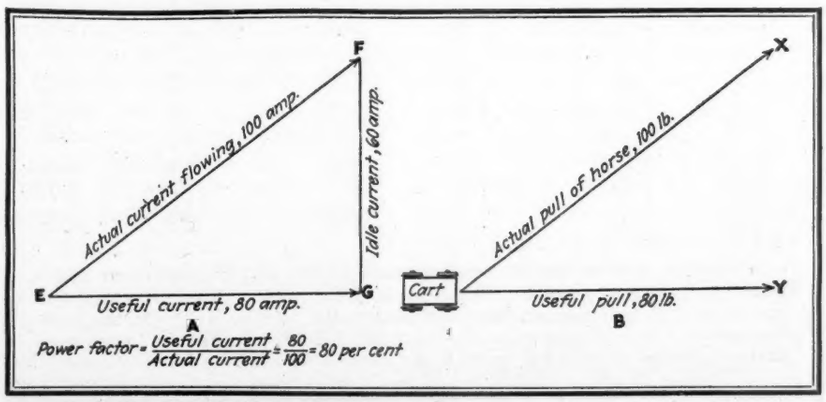
It is not the purpose of this article to deal with the methods used for power factor correction, but the four general types of equipment used may be mentioned and discussed briefly. Synchronous motors, combination synchronous-induction motors (the Fynn-Weichsel type), static condensers, and synchronous condensers may be used, each type of corrective equipment having its field of application, depending upon the particular conditions. Generally it is more economical to use either the first or second methods, as these motors replace low power factor induction motors which, if they were not removed from the lines, would have to be taken care of by additional capacity with either of the two latter methods. Static condensers may be best under certain operating conditions where power factor correcting motors cannot be used. The installation of synchronous condensers in industrial plants is seldom justified on account of the high operating costs in the comparatively small sizes required. However, central stations find use for them in large sizes where the initial investment per unit of correction is lower and the power required to drive them can be supplied by the excess generating capacity at very low cost.

For the purpose of explaining the fundamental conceptions of power factor an analogy has been given between the flow of a fluid in a system of piping and the flow of electricity in a distributing system. In dealing with practical problems such as are encountered when estimates are made of the size of corrective equipment required, or when it is desirable to check power factor measurements or calculations, it becomes necessary to use a mathematical representation of actual conditions. For this purpose a right-angled triangle is used such as is shown in diagram *A* of the illustration. The longest side, *EF*, of this triangle represents the actual current flowing. As shown, the useful current is only 80 per cent of this; hence the power factor is 80 per cent, since power factor has already been defined as the ratio of useful current to the total amount of current flowing.

The physical explanation of this is illustrated by diagram *B*. Assume that a horse pulling in direction *X* is attached to a cart which has the wheels set to move in direction *Y*. With an actual pull by the horse of 100 lb., it is apparent that only 80 lb. are available to pull the cart in direction *Y*. By making use of the same reasoning that power factor in an electric circuit is the ratio of useful to actual current, we might say that the "power factor" of the horse is the ratio of useful pull to actual pull, or in this particular case, 80 per cent. If the total current, 100 amp., in diagram *A* were all useful, the power factor would be 100 per cent, and if the horse pulled its full 100 lb. in direction *Y* his power factor would also be 100 per cent.

Where the power company has a rate that involves power factor it is necessary for them to make some

These diagrams show the analogy between power factor in an electrical circuit and the use factor of a mechanical force.



sort of measurement to determine just what the power factor is in a given case. The use of a meter to measure and record power factor directly is not practicable for small systems on account of the high cost and complexity of such an instrument. It is customary, therefore, to measure the useful current or power (which is always done whether there is a power factor rate or not) and the so-called "idle" or useless component. In diagram *A* this component is the side *FG* of the triangle. Then by a simple calculation power factor is determined from these two readings. This method is based on the use of two standard, polyphase watt-hour meters, one of which may be the regular service meter connected in the usual manner. The other meter, which is identical with the first one, is connected to a so-called "phasing transformer" to give the 90-deg. displacement, as between the lines *EG* and *FG* in diagram *A*.

In order to calculate power factor from the readings of the first or kilowatt-hour meter and the "idle" or reactive meter, as it is generally called, it is only necessary to make use of a simple mathematical theorem which states that the hypothenuse of a right triangle is equal to the square root of the sum of the squares of the other two sides. Thus in diagram *A*,

$EF = \sqrt{80^2 + 60^2} = \sqrt{10{,}000} = 100$,

and, Power factor $= EG \div EF = 80 \div 100 = 0.8$, or 80 per cent. Therefore, if at the end of the month the kilowatt-hour meter reads 20,000 and the reactive meter 25,000, the power factor is found as follows:

Power factor equals $20{,}000 \div \sqrt{20{,}000^2 + 25{,}000^2} = 20{,}000 \div 32{,}020 = 62.5$ per cent.

In order to avoid making these calculations each time, the accompanying table has been prepared, showing the power factor corresponding to the various ratios of the reactive to the kilowatt-hour meter readings. Thus in the example just cited, Reactive hours ÷ Kilowatt-hours = 25,000 ÷ 20,000 = 1.25. Reference to the table gives a power factor of 62.5 per cent for the ratio of 1.25.

The "kilowatt hour-reactive hour" system of power factor metering is inaccurate in that it gives the average or effective power factor for the full period covered by the power bill, including transformer "reactives" at night and on Sundays and holidays when little or no power is being used. A more accurate method of determination would give the power factor at the time of the peak load, as this is really the only time the power company is vitally concerned with the consumer's power factor. However, in defense of this system of metering, it must be understood that present-day metering facilities make most other methods impracticable. Probably the kilowatt-reactive method will continue in favor for some time.

It is not possible to determine directly the power factor of a load at a particular time, if the kilowatt-hour meter and a reactive-hour meter are installed, as the readings are cumulative. However, if the ratio of the number of revolutions of the reactive meter to the kilowatt-hour meter is found by counting the speeds of the disks of the respective meters for a period of three minutes or longer, the power factor can be determined from the table. For example, if the reactive meter makes 250 revolutions in three minutes and the kilowatt-hour meter makes 200 revolutions in the same three-minute period, the ratio of 250 to 200 is 1.25, which, according to the table, indicates a power factor of 62.5 per cent.

An indicating power factor meter can be purchased at small cost by the power user and is useful in checking the power factor on various feeders to locate that part of the plant equipment which is causing the low power factor. A portable instrument is capable of still wider use, although a permanent installation ahead of all feeder switches or fuses permits checking individual circuits, provided all load except that which is to be measured is cut off the lines.

Power factor rates are now in operation in many sections of the country. In some cases a bonus is offered for high power factor; in others a penalty is imposed unless the power factor is maintained at a

(*Please turn to page 315*)

Determination of Power Factor From Readings of Reactive and Kilowatt-Hour Meters

Ratio of React.-Hr. to Kw.-Hr.	Power Factor	Ratio of React.-Hr. to Kw.-Hr.	Power Factor	Ratio of React.-Hr. to Kw.-Hr.	Power Factor
0.00	1.00	0.76	0.795	1.35	0.595
0.10	0.995	0.78	0.79	1.37	0.59
0.14	0.99	0.79	0.785	1.39	0.585
0.18	0.985	0.80	0.78	1.40	0.58
0.20	0.98	0.82	0.775	1.42	0.575
0.23	0.975	0.83	0.77	1.44	0.57
0.25	0.97	0.84	0.765	1.46	0.565
0.27	0.965	0.86	0.76	1.48	0.56
0.29	0.96	0.87	0.755	1.50	0.555
0.31	0.955	0.88	0.75	1.52	0.55
0.33	0.95	0.90	0.745	1.54	0.545
0.35	0.945	0.91	0.74	1.56	0.54
0.36	0.94	0.92	0.735	1.58	0.535
0.38	0.935	0.94	0.73	1.60	0.53
0.40	0.93	0.95	0.725	1.62	0.525
0.41	0.925	0.96	0.72	1.64	0.52
0.43	0.92	0.98	0.715	1.66	0.515
0.44	0.915	0.99	0.71	1.69	0.51
0.46	0.91	1.01	0.705	1.71	0.505
0.47	0.905	1.02	0.70	1.73	0.50
0.48	0.90	1.03	0.695	1.76	0.495
0.50	0.895	1.05	0.69	1.78	0.49
0.51	0.89	1.06	0.685	1.80	0.485
0.53	0.885	1.078	0.68	1.83	0.48
0.54	0.88	1.09	0.675	1.85	0.475
0.55	0.875	1.11	0.67	1.88	0.47
0.57	0.87	1.12	0.665	1.90	0.465
0.58	0.865	1.14	0.66	1.93	0.46
0.59	0.86	1.15	0.655	1.96	0.455
0.61	0.855	1.17	0.65	1.98	0.45
0.62	0.85	1.18	0.645	2.01	0.445
0.63	0.845	1.20	0.64	2.04	0.44
0.65	0.84	1.22	0.635	2.07	0.435
0.66	0.835	1.23	0.63	2.10	0.43
0.67	0.83	1.25	0.625	2.13	0.425
0.69	0.825	1.27	0.62	2.16	0.42
0.70	0.82	1.28	0.615	2.19	0.415
0.71	0.815	1.30	0.61	2.23	0.41
0.72	0.81	1.32	0.605	2.26	0.405
0.74	0.805	1.33	0.60	2.29	0.40
0.75	0.80				

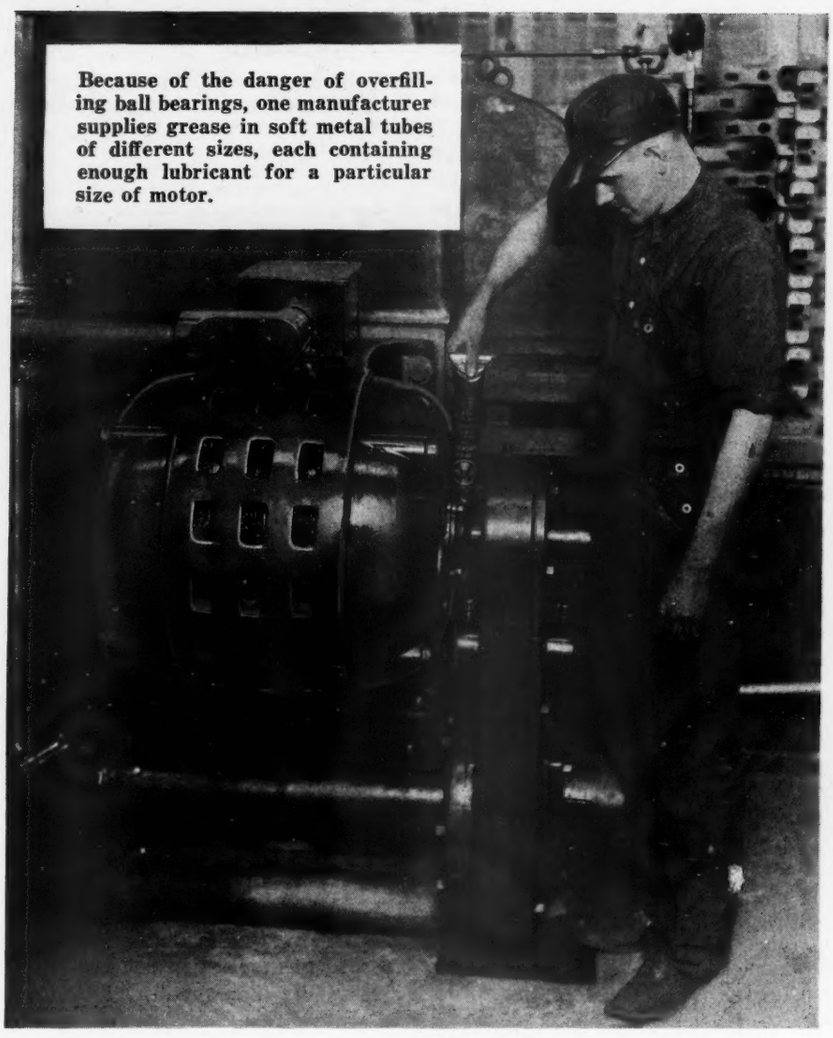
Example: Assume reactive meter reads 25,000 and kilowatt-hour meter 20,000 for the same month; 25,000 ÷ 20,000 = 1.25. Find this figure in one of the columns headed "Ratio of React.-Hr. to Kw.-Hr." On the same line and in the next column to the right headed "Power Factor," the power factor is found to be 0.625 or 62.5 per cent.

PROPER LUBRICATION of the bearings used on power drive equipment is extremely important from the standpoint of insuring continuity of power service and reducing maintenance costs. In particular, the lubrication and care of motor bearings merit very careful consideration, inasmuch as failure or trouble with them leads to complete shutdown of the driven machines. In addition, the lubrication of motor bearings presents several problems which are not ordinarily encountered. Some of these problems and the methods of overcoming them are discussed in this article.

Problems in

Lubricating Motor Bearings

with a discussion of some of the methods used by manufacturers of motors and bearings to reduce operating troubles



Because of the danger of overfilling ball bearings, one manufacturer supplies grease in soft metal tubes of different sizes, each containing enough lubricant for a particular size of motor.

By FRANK E. GOODING
Associate Editor, Industrial Engineer

PREVIOUS articles* of this series on lubrication have discussed lubricants and the general methods of applying them. This article will treat specifically the lubrication of electric motors. It is, of course, impracticable in a restricted article of this nature to discuss each of the numerous makes of motors because in many cases the method of lubricating the bearings is quite similar in several makes. The treatment of the subject here will, therefore, be confined to a discussion of the different methods of lubricating motor bearings.

A motor has two vital parts: the windings and the bearings. Failure of either will stop the motor. It is necessary in an article of this nature to make frequent reference to bearings, in any discussion of their lubrication. Incidentally, a failure or excessive wear on a bearing often results in damage to, or destruction of, the winding also, particularly on direct-current motors. Ordinarily, however, the type of winding has no effect upon the bearings and their lubrication except that provision must be made to keep the lubricant from getting on the windings. Some of the methods of doing this will be described later in this article.

The problems involved in the lubrication of motors are important because of the dependence of continuous operation upon the driving unit. If the motor stops for any reason, the equipment driven by it also ceases to operate and in many cases, such as when one line of machines feeds to the next, other dependent machines must also be stopped. For example, in group-drive installations each machine can go or must stop in conformity with the operation of the motor. In many process industries stoppage of a motor, due to lubrication or other troubles, often may cause serious loss or damage to the product. Practically every plant has certain "key" operations which serve as the bottleneck of production; it is of vital importance that the motors driving the key machine or machines do not develop trouble or fail.

Because of this necessity of continuous operation motor manufacturers have given considerable attention to the bearings and the provisions for lubrication. These improvements, however, may be nullified by neglecting to lubricate at proper intervals, by using the wrong type of lubricant, and through the lack of sufficient protection against dust or dirt entering the bearings. Even the best bearings and lubricants are not proof against improper use, neglect, and carelessness.

The conditions under which a motor operates also affect the lubricant and, to a certain extent, the selection of the type of bearing. In

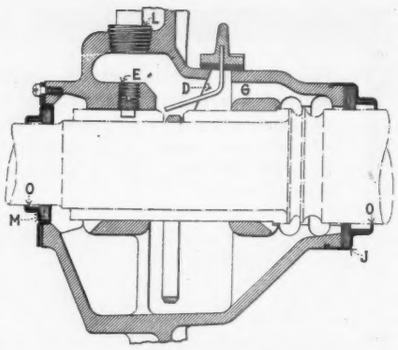
*Articles in this series on lubrication which have appeared in previous issues of INDUSTRIAL ENGINEER are: "Using Oils and Greases for Industrial Lubrication," December, 1925, "Specifications for Oil and Grease Lubricants," March, 1926, and, "Equipment Used for Applying Lubricants," May, 1926.

the case of motors operating under abnormal conditions of heat or cold, or in a dusty atmosphere, special attention must be given to the type of bearing, or the lubricant, or both.

Operation under excessively high or low temperature conditions requires special attention to the type of lubricant, as was mentioned in a previous article. Where the temperature is high, an oil must be used which will have the correct viscosity for the bearing at the higher temperatures. Manufacturers of lubricants provide special oils for use under such conditions. Also, where a motor is exposed to low temperatures a lubricant must be used which has a low "cold test" or congealing point. Similarly, where grease is used in motors exposed to heat or cold, care must be exercised to see that a grease is chosen which will have the proper consistency under the operating conditions.

One of the main problems in the lubrication of motors is to provide a means for the uninterrupted supply of lubricant to the bearings, so as to maintain the film of lubricant between the shaft and its bearing. The methods of doing this vary somewhat with the different makes of motors, but in general they fall within or are modifications of some of the types which will be explained later. These systems of lubrication for the bearings are very similar to the systems used on the same types of bearings for other industrial applications. However, where a bearing is applied to a motor it usually has some improvements or additions over other bearings of the same type when applied to ordinary industrial applications. In general, these improvements consist of better methods of retaining the lubricant in the bearings by preventing it from creeping along the shaft and thus getting onto the windings, as well as more positive means for feeding the lubricant to the bearing.

Wick Oiling—Some form of wick oiling is commonly used on fractional-horsepower motors. Wick oiling devices usually consist of a reservoir for holding the oil and the wick. The wick is generally arranged to press against the side of the shaft; in some cases it is held against the bearings by springs. The oil feeds through the wick and onto the bearings. Rotation of the shaft carries the oil away from the wick and distributes it over the bearings. Lubrication is continuous as long as the motor is in operation,

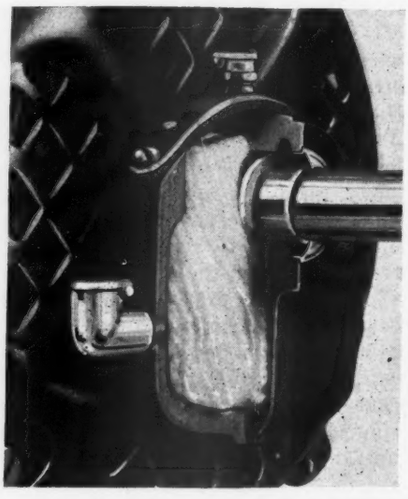


A cross-section of an improved type of ring-oiled sleeve bearing.

Special precautions are taken in this bearing to prevent oil leakage. The opening *G* is a bypass for air to prevent unbalanced air pressure within the bearing. Oil leakage from careless filling is overcome by the inner bearing cap *J*. The cover to the oil ring slot *D* is bolted down against the shellacked felt gasket. The oil ring slot *D* and oiling hole *L* are tightly closed, as shown, which in addition to the felt washer *M* seal the housing against ingress of air and thus prevent currents of air passing through the housing. The bearing cap lip *O* eliminates oil spray from ventilating air by preventing its escape at the housing along the shaft.

but the flow of oil stops when the motor is shut down. Generally the reservoir is large enough to contain sufficient lubricant to keep the wick well saturated for a long period, so that the bearings need to have lubricant added only occasionally.

Some of the advantages of this method of lubrication are that it requires only infrequent attention and is always ready for service at any time, even though the motor is operated infrequently and irregularly.



An example of a wool yarn packed bearing.

This cut-away drawing shows the position of the wool yarn as it is passed around the bearing. Oil is supplied through the spring-closing oil cup at the side. In this way, any dirt which enters the bearings while they are being oiled is not carried up to the shaft. If the bearing were oiled from the top, foreign matter might be washed down into the bearing.

Also, the wick will remain saturated for a time even though the motor, which in the fractional and small horsepower ratings is easily moved, has been upset and the oil reservoir has been drained.

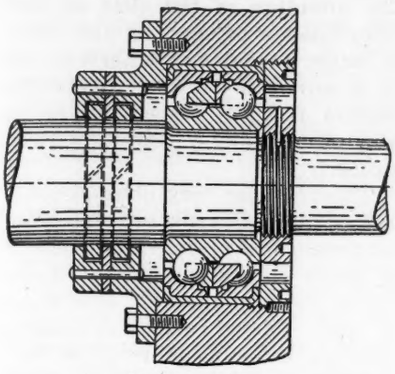
One of the most common means of preventing creeping of oil in wick-oiled bearings is to provide either a groove or opening in the bearings, or a projecting ring or disk on the shaft. As the oil creeps along the shaft it is thrown off from this disk or into the groove by the centrifugal force of rotation. Variations and improvements of this method, some of which will be shown and discussed later, are perhaps the most common means of preventing the oil from creeping along the shaft and entering the windings of the motor.

Lubrication by Packed Waste or Wool Yarn—The wool yarn method of lubrication is also frequently used on fractional-horsepower motors. This method of lubrication differs somewhat from the wick system in that the oil reservoir is usually of greater capacity, and the yarn is considerably larger than the wick. Long strands of wool yarn are used to carry the lubricant from the oil reservoir to the top of or side of the shaft by capillary action.

Bearings packed with waste instead of yarn are used on motors of larger size. Packing with waste serves much the same purpose as the yarn in the fractional-horsepower motors in that it carries a continuous supply of the lubricant to the surface of the shaft.

One of the most common applications of waste-lubricated bearings is in street railway motors. This same method is frequently used in industrial applications; however, the method of filling the bearing or oil reservoir with the waste or yarn is of considerable importance. The lubricant is carried up to the bearings along the strands of the fiber by capillary action. The waste also serves as a filter to separate out particles of dust or dirt from the lubricant and prevent them from working into the bearings.

It is necessary for the best results to have the strands of the waste or yarn run in parallel lines as nearly directly from the oil reservoir to the bearing as possible. A bearing should never be packed by merely cramming it full of waste or yarn. A better way is to fold the waste or yarn into a skein long enough to



Here two split rings are fitted to the shaft and turn in grooves in the housing.

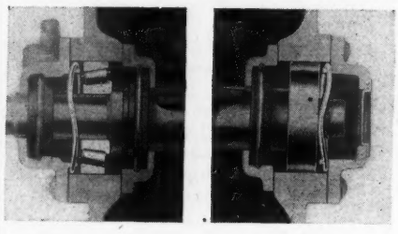
These rings form an effective oil and dust seal. Where oil is used in ball bearing motors, a more effective seal must be provided than where grease is used, because oil creeps much more easily than will grease.

reach from the top of the bearing to the bottom of the oil reservoir. It should be held in position by packing in more waste yarn.

In motors operating under high temperature conditions, which may be due either to the surrounding temperature or to heat transmitted to the shaft from the motor, the waste which comes in contact with the shaft is frequently baked or glazed. This retards the capillary flow of the oil and can be determined only by inspection, which should be frequent whenever conditions are such as described.

It is usually best to fill such bearings from the side or bottom of the reservoir, through a pipe extending out to the side, rather than to pour the oil down through the top of the bearing because of the danger of washing dust particles down through the waste or yarn and into the bearings with the oil. The top opening should be sealed and used only for inspection or repacking. Also, as with practically all other types of bearings, it is not wise to fill them too full of oil because of the additional danger of the oil creeping past any barriers and getting into the windings. With almost any type of bearing, there is seldom any excuse for filling it so that the level of the oil is high enough to touch the bottom of the shaft. This is not true, of course, of grease-lubricated ball bearings.

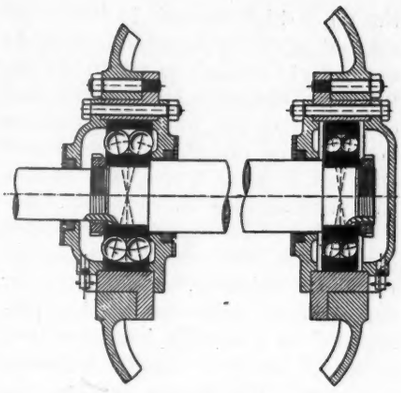
It is also well to provide an oil gage or some means of indicating the depth of oil in the reservoir both for inspection and to indicate the oil level to the oiler. Care must be exercised to see that this gage line does not fill up. Ordinarily the gage is on the same line as is used to fill the bearing.



The tapered roller bearings in this motor are arranged for grease lubrication. The bearings are sealed to retain the lubricant and keep out foreign matter.

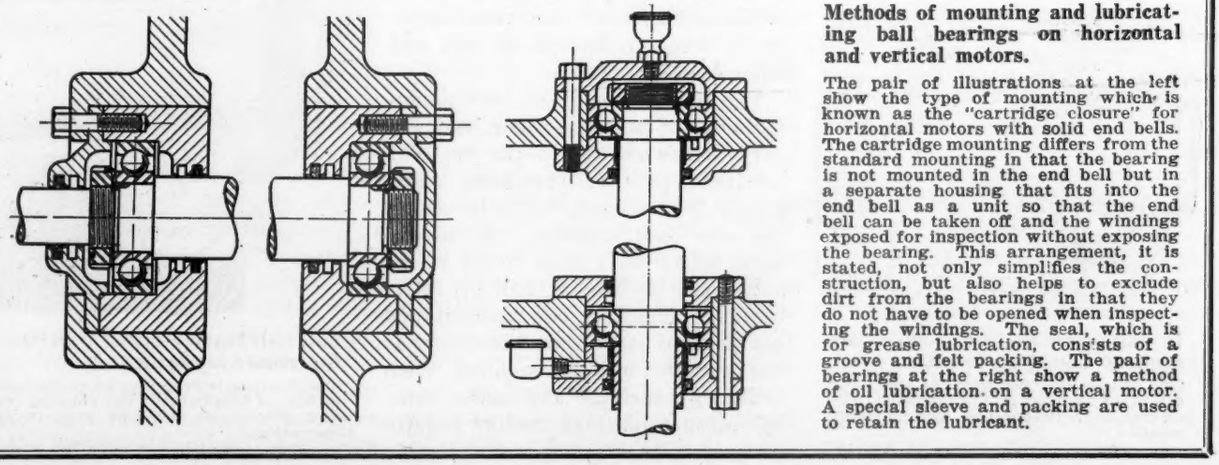
Ring Oiling — One of the best known methods of lubricating motors is by means of a ring oiler. Briefly, the elements of a ring-oiling bearing consist of a bearing, shaft, an oil reservoir, a loose ring, and provision for preventing oil creep. The ring fits on the shaft and dips down into the oil reservoir; the rotation of the shaft turns the ring which carries oil up from the reservoir and deposits it on the shaft. Some of the advantages of this type of bearing are that it is simple, lubrication is positive, and there is little chance for anything to get out of order.

With some of the old type bearings difficulties resulted from the ring sticking to the side of the groove in which it fits, or jumping out of its groove; in most modern motor bearings these difficulties have been overcome. Where ring-oiling bearings have given trouble from excess oil on windings, it has often been traced to the practice of filling the bearing too full of oil, which does not permit the functioning of the "oil thrower," or other means of preventing "creep." Where



Another method of installing ball bearings for grease lubrication on a motor.

In this case the housing seals or shaft enclosures are of the felt washer type, which will effectively prevent leakage of the grease provided a suitable lubricant is selected. The grease should have a higher melting point than the highest temperature attained by the bearing in operation. This may be 10 deg. to 50 deg. F. in excess of the temperature of the adjacent parts of the motor, which of course are subject to electrical heating. These bearings have Alemite fittings but the housing should never be filled more than one-third to one-half full of lubricant.



Methods of mounting and lubricating ball bearings on horizontal and vertical motors.

The pair of illustrations at the left show the type of mounting which is known as the "cartridge closure" for horizontal motors with solid end bells. The cartridge mounting differs from the standard mounting in that the bearing is not mounted in the end bell but in a separate housing that fits into the end bell as a unit so that the end bell can be taken off and the windings exposed for inspection without exposing the bearing. This arrangement, it is stated, not only simplifies the construction, but also helps to exclude dirt from the bearings in that they do not have to be opened when inspecting the windings. The seal, which is for grease lubrication, consists of a groove and felt packing. The pair of bearings at the right show a method of oil lubrication on a vertical motor. A special sleeve and packing are used to retain the lubricant.

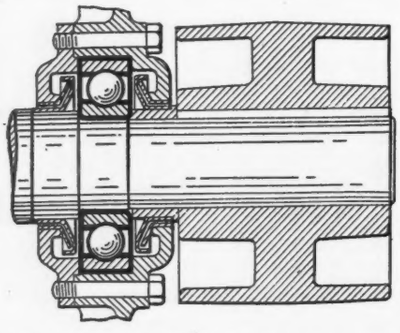
the oil is high enough to touch the shaft it is almost impossible to make a seal tight enough to retain the oil. With the reservoir too full the feed of the oil to the bearings keeps so much oil on them that the excess does not have an opportunity to flow back directly into the reservoir.

Another difficulty with ring-oiled bearings is often due to inadequate reservoir capacity. The reservoir serves three purposes, namely; for storage, as a settling chamber, and to permit the oil to cool by radiating the heat. Where the reservoir is too small, the ring keeps the oil agitated and does not give impurities an opportunity to settle. This difficulty can sometimes be remedied by inserting a short length of pipe with a cap on the end into the drain opening. This increases the capacity of the reservoir and also provides the length of pipe as a settling and cooling chamber.

Another method of preventing oil creepage, in addition to the disk or oil thrower and grooves, is by means of felt or composition wiping rings. These also serve to prevent the entrance of dust.

The rate of flow of the oil through the bearing to the reservoir is controlled largely by the grooves in the bearings and the viscosity of the oil. If an oil has too high viscosity and flows too slowly through the bearing grooves it may cause trouble. This may be remedied by selecting a lubricant of lower viscosity. However, if the bearing is to operate under conditions of high temperature, it is well to use an oil of somewhat higher viscosity than for ordinary conditions, because the effect of the heat is to thin the oil and decrease its viscosity.

Within the past few years motor manufacturers have directed considerable effort toward the improvement of sleeve bearings and the ring oiler. Many such bearings, which are very reliable even under adverse conditions, are now available.



In this case the oil slingers are made of thin sheet metal.

One slinger revolves with the shaft and the other is fixed to the housing. The clearance between the two is very small.

Specifications of Grease for Ball Bearings

The essential characteristics of a suitable grease for use on ball bearing motors, as given by one manufacturer, are as follows:

(1) Consistency should be a little heavier than that of vaseline. About Nos. 2 or 3 as graded by automobile grease manufacturers. A grease of this consistency is stiff enough not to churn at high speeds, yet soft enough to protect the balls and races.

(2) Melting point should be as h. . as possible—180 deg. F or higher.

(3) Grease should have no tendency to gum or harden.

(4) Grease should not contain abrasive or body-giving matter, such as talc, graphite, or ground pumice.

(5) It should be made on a mineral base—not vegetable or animal.

(6) Free acid or alkali should not run over 0.1 per cent.

(7) Consistency of the grease should not change at lowest outside and maximum motor temperatures.

(8) There should be no tendency to separate while standing.

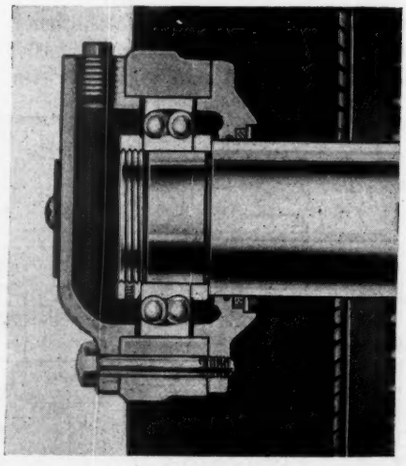
Ball and Roller Bearing Lubrication—During the past few years, manufacturers of electric motors have been giving increasing attention to the demands of motor users for bearings which will stand up under severe operating service over a long period of time, even though it might be difficult to get at them for regular and frequent oiling. This was particularly true of motors operating under severe conditions and where they are difficult of access. The solution of such operating problems has been met very extensively through the use of ball and roller bearing motors.

The recommendations of manufacturers of ball and roller bearings vary somewhat as to the type of lubricant to use. In some cases grease is preferred, while in others oils are used. Among the advantages which have been found to result from the use of ball or roller bearings in motors, one which stands out perhaps more than the others is the reduction of labor in oiling. With ordinary bearings, and under some operating conditions, motors require the attention of the oiler at least once a day or oftener; in other cases, a longer period may intervene, but it is advisable at least to give the motors frequent inspections to see that the oiling system is working properly.

Except under very unusual conditions it is ordinarily sufficient to oil or grease ball or roller bearings on a motor only about once or twice, or at the most three or four times, a year. Many companies make a practice of adding lubricant at half-year periods and cleaning out the bearings and refilling at the end of the year. This requires only a fraction of the attention and labor necessary where a bearing must receive attention each day. Also, the consumption of lubricants is much less.

The function of the lubricant in a ball or roller bearing is somewhat different from that in other types of bearings in that one of the important purposes is to protect the metal in the balls or rollers from corrosion. For this same reason lubricants should be free from acid or alkali. The metal has a high finish and if it were left exposed would corrode or pit which would be very detrimental to the operation of the bearing. Also, because of the rolling action of the metallic surfaces, instead of sliding friction, as in other bearings, practically no heat is generated and so the lubricant does not have to cool the bearing. In this way a smaller quantity of lubricant is required than in other types of bearings. Consequently, the bearing cavities may be smaller.

Many manufacturers caution users against filling a ball or roller



This ball bearing motor is designed for grease lubrication.

The bearing is sealed against dust and escape of lubricant by the packing ring and groove, as may be seen in the illustration.

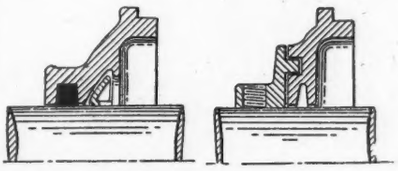
bearing too full of lubricant, and particularly against filling it under pressure. In case such bearings are filled too full of lubricant or under pressure, the churning of the lubricant by the balls or rollers heats up the bearings. Also, if a bearing is filled under pressure there is a tendency for the lubricant to work out of the bearing past any barriers which the manufacturer has placed along the shaft and which will prevent creepage under ordinary conditions. Where a bearing is filled with a grease of too heavy consistency or oil of too high viscosity, there is also a tendency to heat because of the friction of the oil or grease.

As stated before, some manufacturers recommend grease as a lubricant. One of the advantages is that grease is considered less likely than oil to creep along the shaft. Also, it is easier to provide a seal when grease is used. A grease that is so thin that it will flow freely will, it is stated, churn and heat up at speeds around 5,000 r.p.m. One manufacturer, however, recommends greases, of properly selected consistency, for use at speeds up to 7,500 r.p.m. Specifications for a grease for ball bearing motors, as given by one manufacturer, are shown in the accompanying table.

Cleaning—The design of the bearing, the adequacy of the seal, and the service conditions determine the frequency of attention. Ordinarily ring-oiled bearings should be cleaned at much shorter periods than ball or roller bearings. Ring-oiled bearings, however, can operate with contaminated oil better than can ball or roller bearings.

When cleaning, any gummed oil or grease as well as accumulated dirt and grit, should be removed. One method of cleaning the bearing housing is to remove the top and bottom plugs from the housing and drain out the lubricant. Next, replace the bottom plug and fill with kerosene, gasoline, or a light lubricating oil heated to about 200 deg. F. until the oil appears at the oil filling opening. The top plug should then be replaced and the motor turned over by hand a few times to distribute the solvent. In about 10 min. the plugs can be removed and the housing drained; rotate the motor slowly by hand while draining. The bottom plug should then be replaced and about ½ pt. of clean oil poured into the housing; a few turns of the motor by hand will distribute the clean oil and wash out any kerosene or other solvent which might affect the fresh oil. This flushing bath is then drained and the bearing filled to the proper level.

For ordinary motor service, renewing the grease in ball or roller bearings once a year is ample. Under any conditions the most frequent renewal is every three months. At the time of renewal the packing rings should be inspected, if these are used. This is also a good time to note the quality of the grease last used, and to see whether or not it has hardened. The tendency of grease to cake is really what determines the frequency of lubrication and cleaning. In renewing grease care must be taken not to let dirt get into the housing.



Two other types of seals for oil-lubricated ball bearings.

The illustration at the left shows a combination oil slinger and a dust-proof felt washer, which is indicated in solid black. The seal only is shown in both of these illustrations. The illustration at the right shows a combination labyrinth groove to exclude dust and an oil groove which drains back into the bearing housing.

Closure—Each motor manufacturer has methods of his own to close the bearing against leakage, and also against the entrance of foreign material. A few of these methods are shown in some of the accompanying illustrations. The discussion of each closure is given in the caption accompanying the illustration. It may be said, however, that in general the purpose of the end bell of a ball or roller bearing motor is to perform three functions: (1) To hold the outer ring of the bearing and do this in such a way as to make assembly and disassembly easy. (2) To retain lubricants. (3) To exclude foreign matter. Some of the means of doing this may be seen from a study of the illustrations.

It is easily seen, therefore, that the selection of the proper type of lubricant is of great importance. The manufacturer's recommendation can be taken in any case where a motor is operating under any ordinary conditions. If abnormal service conditions are involved, it is well to consult with either the manufacturer of the motor or the bearings, or both.

Low Power Factor Causes Trouble

(*Continued from page 310*)

certain point. Some rates adjust only the demand charge for power factor; others charge only the energy rate, while a few adjust both demand and energy charges in accordance with a fixed schedule.

One of the simplest rates now in operation specifies that for each 1 per cent by which the power factor is maintained above 90 per cent, a discount of 1 per cent will be allowed on the demand charge; whereas, for each 1 per cent by which the power factor is below 80 per cent, a penalty of 1 per cent will be imposed. This rate has been used satisfactorily for over a year on the lines of an operating company in Northern Indiana.

Another rate which has been quite popular does not include a penalty clause, but specifies a discount of 5 per cent if the power factor is maintained over 80 per cent, and a discount of 10 per cent if it is kept at 90 per cent or better. The Rockford, Ill., Electric Company uses this rate.

Probably the most widely used power factor rate is based upon an average or effective power factor of 85 per cent. It operates as follows:

Average Power Factor	Multiply Kw.-Hr. by This Constant
1.00	.951
.95	.965
.90	.981
.85	1.000
.80	1.023
.75	1.050
.70	1.0835
.65	1.1255
.60	1.1785
.55	1.2455
.50	1.3335

An examination of this rate will disclose the fact that low power factor results in greatly increased bill, while high power factor gives a substantial reduction. This rate is used by the American Gas and Electric Company properties in Indiana, Michigan, Ohio and elsewhere.

Another widely used rate is based upon the following equation:

Net billing = (regular billing × .85) ÷ average power factor.

At 50 per cent power factor a penalty of 70 per cent is imposed, while at 100 per cent power factor, a bonus of 15 per cent is earned.

Methods of raising the power factor of an industrial plant will be discussed in other articles which will appear in succeeding issues.

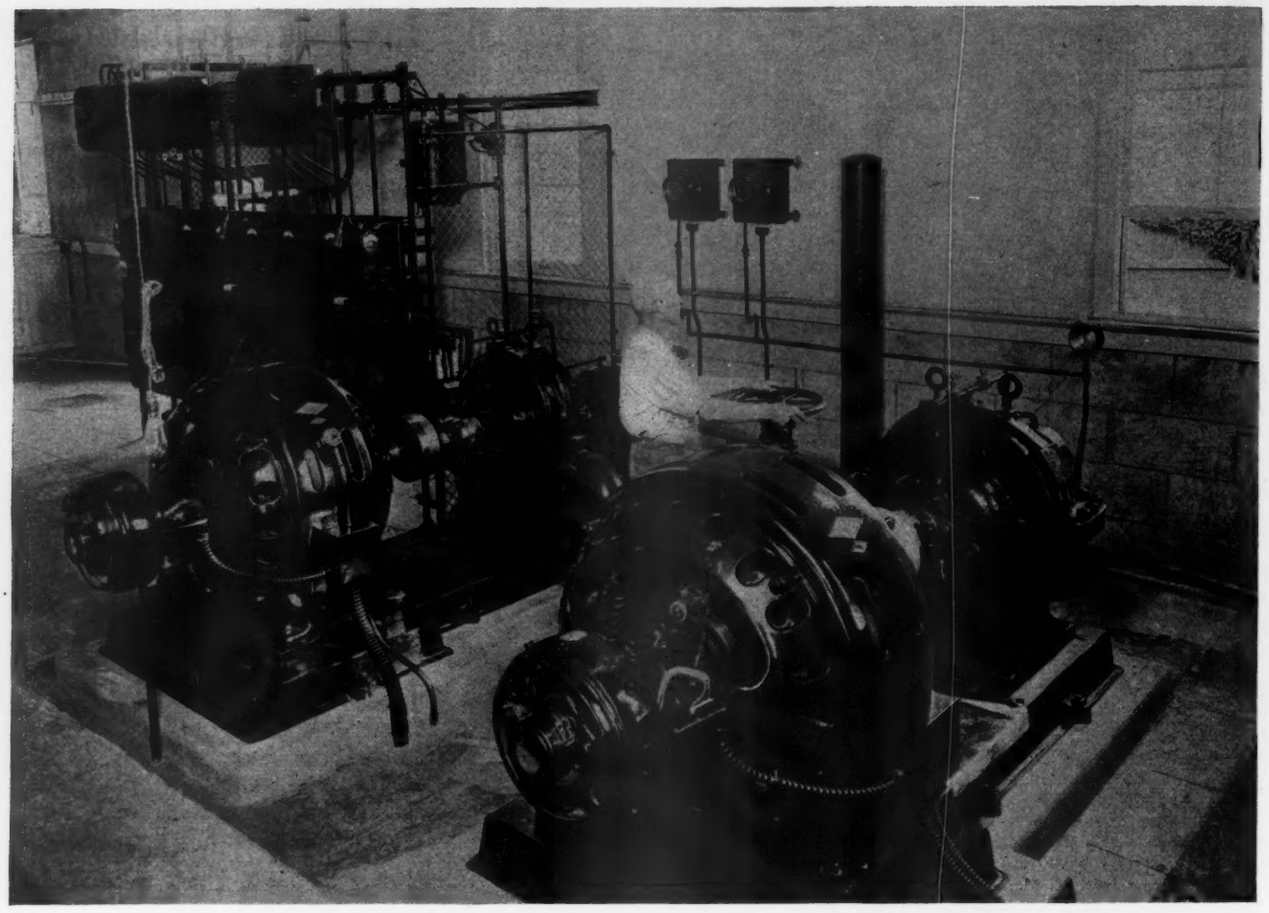


Fig. 1—The synchronous motor is particularly adapted for driving constant-speed centrifugal pumps.

These two 200-hp., 1,500-r.p.m., 2,200-volt Electric Machinery Co. synchronous motors are driving Worthington single-stage centrifugal pumps. Exciters of 2-kw. capacity are direct-connected to the motor shaft. The control for the motors may be seen in the left background.

Power Drive Equipment for Industrial Pumps

together with a discussion of their operating characteristics which affect the selection of the motor, control, and drive connection

BY GORDON FOX
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THE preceding article on the application of motors to pumps, published in the May issue, gave the details of the operating characteristics of reciprocating, rotary, and centrifugal pumps and discussed briefly the application of motors to them. This article will go more into detail regarding the selection of motors, control, and drive equipment for the different types of pumps.

In the majority of pump drives approximately constant quantities and heads are involved. If this is not the case the best method of meeting the range of requirements should be carefully considered.

With a reciprocating or rotary pump the quantity of liquid delivered is closely proportional to the speed and almost independent of the head. Reduction in quantity can be obtained either by a reduction in speed or by an overflow provision, the latter being relatively wasteful. A reciprocating pump working against a given head requires constant torque at any speed, and the horsepower is in proportion to the speed at which the pump is operated.

In the case of the centrifugal pump, delivery can be reduced by reducing the speed or by throttling, which increases the head against the pump and thereby decreases the quantity. Let us consider the effect of change of speed on a centrifugal pump.

A change in pump speed causes a change in the head developed by the pump and also a change in volume.

Fig. 2 shows the characteristics of a pump at normal speed and at speeds above and below normal over a limited range. A series of efficiency curves are included which indicate at their intersections with the head-capacity curves, the conditions which give 100 per cent, 95 per cent, etc., of maximum pump efficiency. Let us assume that the maximum efficiency of this pump is 70 per cent. The pump has this efficiency at 100 per cent rated speed and 100 per cent rated capacity, also at 110 per cent speed and 110 per cent capacity, etc. At 110 per cent speed and 75 per cent

capacity, the pump has an efficiency of 92 per cent of 70 per cent, or 64.3 per cent.

It should be noted that the pump manufacturers' characteristic curves are based on a fixed speed. These curves are somewhat modified by the speed regulation of the motor, tending to give increased droop to the capacity-head curve. This effect should be borne in mind particularly when compound-wound motors or variable-speed, wound-rotor motors with secondary resistance are used. In exceptional cases it may be desirable to modify the pump characteristics by this means.

When the speed of a pump is increased, the point of maximum efficiency occurs at a higher head and greater volume than at normal speed. When the speed of a pump is reduced below normal speed the point of maximum efficiency occurs at a lower head and lesser volume than at normal speed. This can be seen from inspection of Fig. 2.

If a centrifugal pump is operated against a constant head and if the speed be changed to vary the output, the pump efficiency will change materially, due to the different portions of the characteristic curves on which the pump will be worked. Fig. 3 is of interest in this connection. In it are shown how the volume, head, efficiency, and power vary with changes in speed in the case of the pump whose characteristics are shown in Fig. 2. It is assumed that this pump operates against a fixed static head of 80 per cent of rated head. The balance of the system head is friction head; thus at rated delivery, the friction head is 20 per cent of rated head.

Due to the presence of the static head the effect of speed changes can be determined only by study of the characteristic curves at the different speeds. It will be seen from Fig. 3 that this pump will deliver little or no volume until it exceeds 80 per cent speed; thereafter the volume increases faster than in direct proportion to the speed. The total head increases approximately directly as the speed, and not as the square of the speed. The speed-head curve in this case happens to be an approximately straight line. The efficiency is less at speeds above and below rating because the system characteristic is such that the pump operates slightly off-rating at speeds above and below normal speed. At considerably reduced speeds, when the developed head approaches the static head and the volume decreases, the efficiency falls very rapidly. The horsepower increases from shut-off value at about 80 per cent speed at a rate faster than the cube of the speed. It is also evident from this study that the speed of a pump cannot be reduced greatly below rated speed if the rated head is largely static head.

As explained in the fourth paragraph of this article, the delivery of a centrifugal pump can be reduced by reducing the pump speed or by throttling the discharge. The effect of changing the pump speed has just been considered. Let us now discuss the effect of throttling.

If a centrifugal pump has a flat capacity-head curve a small increase in system head, obtained by throttling, will cause a relatively great decrease in delivery. The loss of power incident to the false head is then moderate. If a pump has a steep capacity-head curve it is necessary to increase greatly the system head by throttling in order to reduce the discharge. The loss due to this false head then becomes a material factor.

A comparison of relative efficiencies of control of delivery by throttling as compared with variation of motor and pump speed, using armature or rotor resistance, must weigh the fact that with varied speed, the combined efficiency of motor and control falls off with reduced load and increased slip, while the water horsepower or pump load rapidly decreases. With throttled discharge the drive efficiency is well maintained, but the pump load decreases only slightly, to an extent dependent upon the pump characteristics.

The feasibility of throttling the discharge for volume control depends to a large extent upon the system characteristic. If the system head is largely static head a reduction in volume is not attended by a great decrease in normal friction head. If the system head is largely or entirely friction head a reduction in volume is normally attended by a material reduction in friction head. In this event the false head must offset this normal decrease in friction head and must introduce

Figs. 2 and 3—How change in speed affects the output of a centrifugal pump.

Fig. 2 shows the characteristics of a pump when operating at normal speed, at 10 per cent below rated speed and at 10 per cent above rated speed. In Fig. 3 is shown how the characteristics of this same pump vary with change in speed. In this graph, volume, horsepower, efficiency and total head are plotted directly against change in speed.

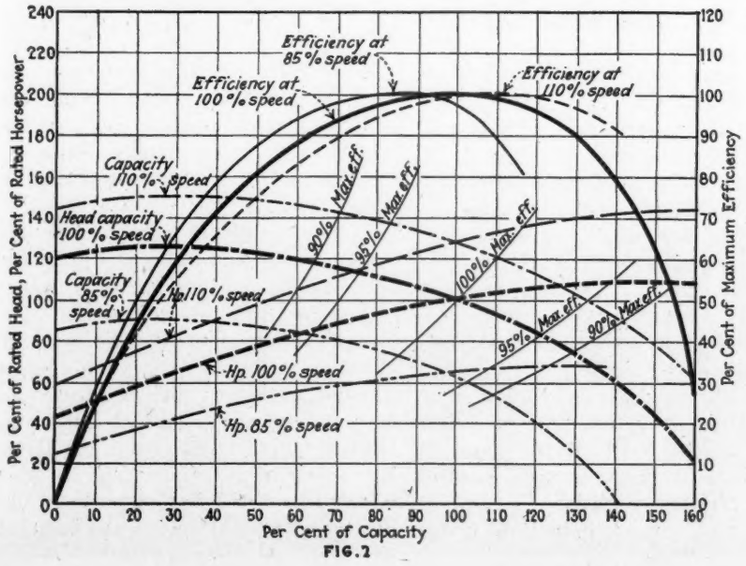


FIG. 2

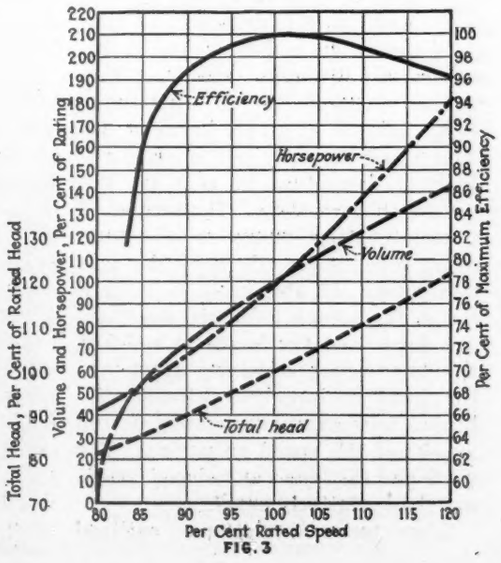


FIG. 3

sufficient additional false head to bring about the desired reduction in volume. The normal decrease in water horsepower due to reduced pipe friction at reduced volumes is thus absorbed in throttling with a material loss in economy. Where the system head is largely static head the losses due to throttling are less pronounced.

Small centrifugal pumps are more commonly operated at constant speed, the delivery being controlled by throttling. For the larger pumps, particularly if they are to be operated for long periods at reduced delivery, it is advisable to calculate the electric power consumption with the different methods and to determine whether the saving, if any, using adjustable-speed drive, will justify the greater investment incident to this type of drive. In this connection it may be well to call attention to the considerable power loss which may arise through the not uncommon practice of installing oversize pumps and throttling the discharge. A few feet of false head will more than offset any possible savings in electrical energy.

Application of Motors to Variable-Speed Pumps

Where speed adjustment of pumps is desired, the wound-rotor induction motor is most commonly used. As the load is ordinarily of a non-fluctuating character and as the speed range desired is usually small, this method is quite satisfactory as to performance. The loss in the secondary resistors is an item, but it is ordinarily not serious where only a small speed range is involved.

In laying out the resistance for speed control of wound-rotor motors used on pumps, it is necessary to consider the torque requirements of the pumps at different speeds. The torque required by a centrifugal pump falls off at a rate between the square and the cube of the speed reduction, depending in part on the system characteristic. The torque of a reciprocating pump or a rotary pump depends directly upon the system head. If the head is largely static, the torque is nearly constant. The loads and the losses at reduced speeds are then relatively great. If the head is largely frictional, the torque falls off approximately as the square of the speed reduction. The loads and the losses at reduced speeds are then relatively small.

The torque relations outlined above must be considered in proportioning the secondary resistance for speed control of a wound-rotor induction motor in pumping service. It is customary to supply resistors proportioned for constant torque for use with reciprocating pumps and proportioned for "fan duty" for use with centrifugal pumps, unless otherwise specified. It will be seen that in some cases such design is not entirely correct.

The brush-shifting commutator motor is well adapted in its characteristics for driving centrifugal pumps where speed adjustment is desirable. The principal deterrents to the use of this type of motor are its higher first cost and somewhat greater complication. In any specific case the economy of this type of drive, as compared with the wound-rotor induction motor with secondary resistance, should be evaluated for justification of the higher first cost. Ordinarily this type of motor can be justified only if the pump is to operate at reduced speed continuously for long periods.

The multi-speed induction motor has been successfully applied in several instances where two fixed speeds will suffice, notably for surface condenser circulating pumps. The lower speed usually will be about 75 per cent of the higher speed. The horsepower required at the lower speed is materially less than at the higher speed, the exact relation depending upon the system and pump characteristics.

It is sometimes feasible to supply two motors of different speeds, each motor being large enough to drive the pump at its respective speed. This method involves a high first cost but there may be a material power saving as compared with the use of a wound-rotor induction motor. Also the power factor, when using this method, at the lower speed, will be better than that of the multi-speed motor. This type of drive can be justified in case of long periods of operation at a reduced speed.

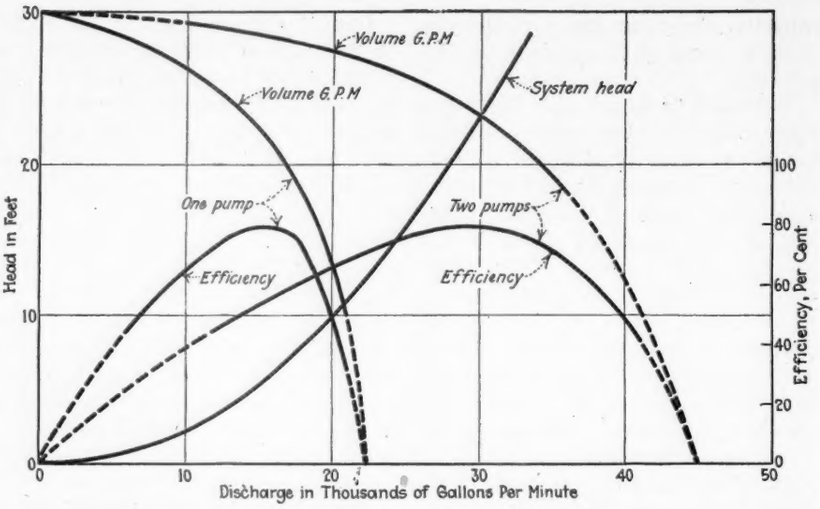


Fig. 4—Two duplicate pumps operated in parallel will not commonly deliver twice the quantity delivered by one pump.

This is due to the fact that the increase in system head incident to the greater quantity of liquid pumped may cause the combination of pumps to operate higher on the system head curve. From the volume curve it may be seen that one pump operating on the required system head, as shown by the intersection of the volume and system head curves, will deliver 21,000 g.p.m. at an efficiency of 40 per cent, while two pumps will deliver only 30,000 g.p.m., but at an efficiency of 80 per cent. Although the addition of a second pump increases the quantity pumped by only 43 per cent, yet the efficiency of operation is doubled by using two pumps; hence the use of two pumps is more economical in this case. The opposite condition is shown in Fig. 7.

Using Two Pumps to Supply Variation in Demand

Not infrequently variation in water requirement is met by the use of two or more pumps, the number of pumps in service being suited to the demand. In this connection it should be noted that on a given system, two duplicate pumps will not commonly deliver twice the quantity delivered by one pump. This is due to the fact that an increase in system head incident to the greater quantity may cause the pumps when in combination to operate higher up on the head curve and at lesser deliveries than when running alone. The efficiency of the pumps is also affected by the different point of operation. These relations are brought

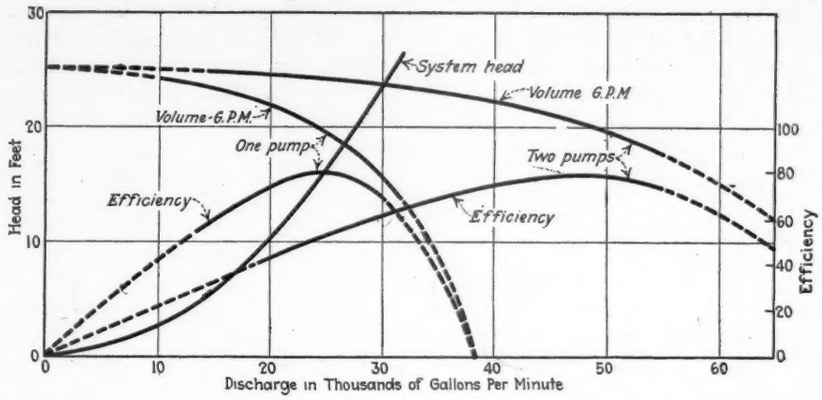


Fig. 7—Pump efficiency must always be investigated when using two identical, constant-speed centrifugal pumps.

This graph shows the characteristics of two pumps differing from those shown in Fig. 4, but operating on the same system. The intersection of the system head curve and the volume curve for one pump gives a volume or capacity of 27,000 g.p.m. at a pump efficiency of 80 per cent. Two pumps operating in parallel deliver only 11 per cent more or 30,000 g.p.m. and both pumps operate at 60 per cent efficiency. Hence it is much more economical to operate the pumps singly.

out clearly in Figs. 4 and 7. Fig. 4 shows two duplicate pumps driven at constant speed. The application is such that the best pump efficiency is obtained when the two pumps operate in parallel. Fig. 7 shows two duplicate pumps differing from those shown in Fig. 2 but operating on the same system. In this case the best efficiency is obtained when the pumps operate singly. The proper pump selection in such a case depends upon whether single or parallel operation prevails.

In Figs. 4 and 7 the system head is entirely frictional. Where static head is more predominant and the system head curve is flatter, the differences between single and parallel performance are less marked.

Where direct current is available the adjustable-speed motor may be employed to provide speed control. Armature resistance control instead of shunt field control of speed may also be used, thus paralleling the performance of the wound-rotor induction motor. The higher efficiency of the adjustable-speed type motor ordinarily warrants its selection in case of extended operation at reduced speed. It is permissible that an adjustable-speed motor for pump drive have a higher horsepower rating at high speed than at low speed.

Where alternating current only is available it is seldom feasible to convert to direct current in order to utilize the adjustable-speed, direct-current motor for a pump drive. The conversion loss offsets any possible power saving, giving little justification for the investment involved. Where both alternating and direct current are available the relative costs of the two services must be considered in making a selection.

Where a standpipe or other sufficient storage provision exists, the delivery of a given constant-speed pump may be varied by operating the pump intermittently, automatic control being provided, this in turn being governed by a float or pressure switch. This arrangement necessitates starting the pump under load. It also requires a storage sufficient, with respect to pump capacity and service demand, so that periods of pumping and rest will not be of too brief duration.

If a centrifugal pump delivers to a system upon which a standpipe floats, the delivery of the pump will automatically vary as the level in the standpipe changes, due to the drooping capacity-head curve of the pump. This automatic adjustment of output, with pumps driven at constant speed, may suffice to meet the variation in demand.

A centrifugal pump delivers a greater quantity at heads below rating. In so doing it requires more than normal driving power. Different pumps vary in degree. Pumps having a steep capacity-head curve will not vary delivery much, except with marked change of head. Pumps with a flat capacity-head curve may deliver widely different volumes, with slight changes in head. Their power demand varies accordingly. Many modern pumps are so designed that the load can exceed rated load

Figs. 5 and 6—Pump drives having heavy starting torque require special provisions for starting.

In Fig. 5, upper view, the 350-hp., 500-r.p.m., synchronous motor is connected to a high-pressure, duplex, reciprocating pump by means of a Cutler-Hammer magnetic clutch. Fig. 6, below, shows three 75-hp., 440-volt, wound-rotor motors driving triplex pumps used for railway water supply purposes. The wound-rotor motors supply a large starting torque and also give variable speed when desired. The motors are controlled by means of Industrial Controller Company automatic secondary-resistance controllers.

relatively little even with free discharge. A pump of this type is "non-overloading" only if it is selected and motored on the basis of its normal rating. If it is selected and motored on the basis of a lower capacity operating point a material overload may be possible.

In selecting a motor to drive a centrifugal pump the size should be based on the power requirement at the minimum head and maximum delivery probable, as the load is then usually greater than with rated conditions. A motor for a "non-overloading" pump should correspond in rating with the maximum load the pump can develop.

The writer recalls a case in which two motor-driven centrifugal pumps operating in parallel delivered to a system having a standpipe. One motor tripped off due to a fault. The other motor and pump operating alone could not maintain the level in the standpipe. As the level fell, the load on the second motor increased until the overload protection tripped this motor and shut down the system entirely. Such conditions must be forecast and provided against.

The load of a centrifugal pump varies rapidly with change in speed. For this reason any condition which may cause a speed increase may lead to overloading the motor. Such conditions might arise through high frequency or, with direct current, through variable voltage or through motor speed above rating. Pumps are commonly designed for full-load, induction-motor speeds. If a synchronous motor is used the fact that it will maintain synchronous speed should be considered.

Not infrequently it is essential that there be no interruption in the operation of pumps where continuity of water supply is of vital importance. Electric drive is sometimes viewed with askance in such cases. If sole dependence is placed on motors every precaution should be taken to protect the source of power and to prevent motor and control faults. In such cases oversize motors may be warranted to enable pumps to "hang on" during periods of low voltage. An induction motor will develop approximately one-quarter of its pull-out torque at half voltage. The usual motor, having a pull-out torque of 250 to 300 per cent, will develop full-load torque down to about 60 per cent voltage. Where under-voltage release or protection is included in the control a time-delay feature may be desirable to avoid shutting down the pump in the event of momentary voltage drop. Not infrequently the under-voltage protection is omitted altogether. Likewise it is not uncommon practice to omit overload protection in favor of differential protection to prevent shutdowns for causes other than faults in the motor, or leads.

Figs. 8 and 9—Remote-control, high-voltage starters for squirrel-cage and wound-rotor motors.

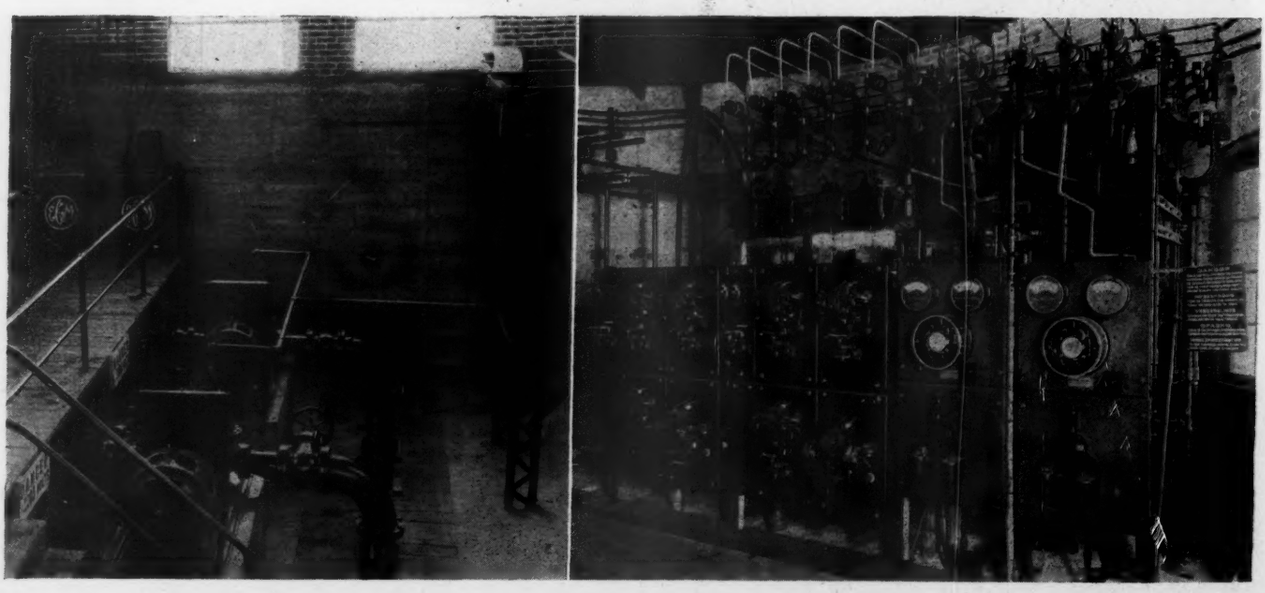
Fig. 8, left, shows an installation of Electric Controller & Mfg. Co. high-voltage compensators controlling two 30-hp., 2,200-volt squirrel-cage motors driving centrifugal pumps used for fire service at the plant of the Ohio Seamless Tube Co., Shelby, O. Fig. 9, right, shows the complete control for two Allis-Chalmers wound-rotor motors driving centrifugal pumps furnishing the water supply for a large steel mill. The motors are rated at 700 hp., 6,600 volts, three phase, 60 cycles and are controlled by Cutler-Hammer remote-control panels.

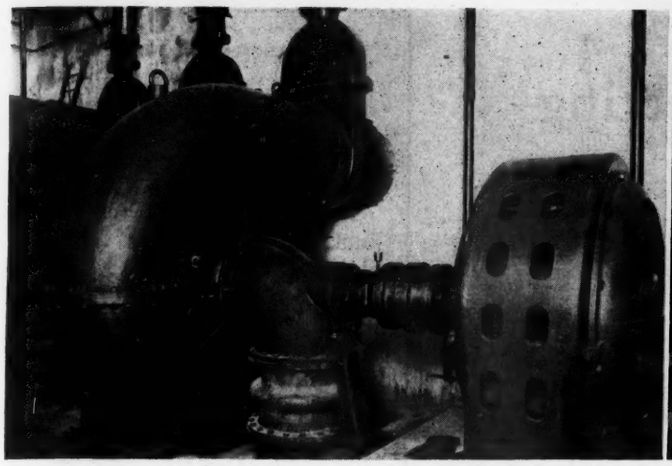
Where undervoltage protection is omitted the motor and control should be adapted for automatic restarting. Squirrel-cage motors with double cage winding for full-voltage starting are particularly suited for this function. Other types of motors can be readily arranged for automatic restarting, particularly if they are equipped with full magnetic control. Automatic restarting is considered highly desirable in some cases.

Starting Requirements of Each Type of Pump

A reciprocating pump, in starting from rest while connected to the system, creates a severe starting condition. Due to the sliding pistons or plungers and tight stuffing boxes the static friction of the reciprocating pump is high. In addition, the positive displacement characteristic requires the development of full pumping torque throughout the acceleration period. If a flywheel is used this adds to the starting requirements. The initial torque of a reciprocating pump may be 125 per cent to 250 per cent of full-load torque. Fig. 5 shows an application of a magnetic clutch so as to permit the use of a synchronous motor on a reciprocating pump drive.

The rotary pump differs materially from the reciprocating pump in starting characteristics. Due to the absence of tight-fitting parts the static friction is less and the "breakaway" torque is lower, being on the order of 30 to 60 per cent of normal full-load torque. As the full pumping torque is immediately demanded, however, the starting duty is not light. It is preferable to un-





Figs. 10 and 11—Motors driving centrifugal pumps are nearly always direct-connected, usually through a flexible coupling.

Fig. 10, left, shows a 300-hp., 190-r.p.m. motor connected by means of a Fast flexible coupling to a dry dock pump of the Baltimore Dry Dock & Shipbuilding Co., Baltimore, Md. Fig. 11, at the right, shows a Francke flexible coupling connecting a 450-hp. motor to the pinion shaft of a Scranton reciprocating pump.

load the pump during the starting interval, by-passing the cylinders so that the water is merely circulated against the head.

Generally speaking, the only load in starting a centrifugal pump from rest is due to the bearing friction and pump inertia; both are relatively small items. As the speed increases the load increases about as the cube of the speed. If the pump is started with the discharge valve closed, the load increases as above, up to the full-speed, shut-off load.

If the pump is started with the discharge valve open, the load increases about as the cube of the speed up to full-speed, full discharge value for the then existing head. If the head on a centrifugal pump is largely static head the pump will not start delivery until well up to speed so that the starting conditions will be relatively favorable. If the head is largely friction head, as in dredging work, the pump will start to discharge at low speed and will accelerate under a relatively heavy load. It is desirable to start the larger centrifugal pumps with discharge valve closed so as to make starting easier.

Type of Control Required by Pump Motors

The form of control used for a pump motor varies with the type of motor used and the service conditions that have to be met. If the pump has to keep the level of a liquid between certain heights or between certain pressures, automatic control must be specified, and should be used in connection with float switches or pressure regulators. On the other hand if the pump is started infrequently and particularly in the smaller capacities manual control will fill the requirements.

Controllers for squirrel-cage motors on pump service may be of the compensator type, the primary-resistance type or, particularly on the smallest sizes, the across-the-line type. The compensator and primary-resistance types are made both for manual operation or for remote control, push-button operation. Fig. 8 shows an automatic compensator. The across-the-line type starter may be a manually-operated enclosed switch or an arrangement using a magnetic contactor.

Wound-rotor motors use a combination of a line switch or contactor and an arrangement for cutting out the resistance in series with the motor secondary. This control may be made up in the form of a manually-operated switch and drum controller or may be arranged with contactors mounted on a panel for remote control. Both of these types are illustrated in Fig. 6. The automatic type is also shown in Fig. 9. For constant-speed service, automatic control is usually preferred. If variable speed is desired, the drum controller is usually specified, although the same results can be obtained with automatic control by using a multi-point master switch.

Synchronous motors are commonly supplied with reduced voltage for starting by means of an auto-transformer or taps from the transformer supplying the power to the motor. In addition to this, control for the d.c. field excitation in the form of a rheostat and field discharge switch must also be provided. Meters giving the field current, power factor, and load current are also desirable. This control may be made up in the manual form as shown in Fig. 5 or may be entirely automatic as shown in Fig. 1.

Brush-shifting, alternating-current motors require only some form of line switch with overload protection and a mechanical means for shifting the brushes. This may be a hand-wheel, a shipper rod, or a small pilot motor controlled by push buttons.

Direct-current motors require a line switch and an arrangement for cutting out the starting resistance. They may be either manually operated or remote controlled. If adjustable speed is desired, a rheostat for regulating the shunt-field current is required.

Motors driving centrifugal pumps are nearly always direct-connected, usually through a flexible coupling, as shown in Fig. 10. Motors driving reciprocating pumps are generally geared through a single reduction to a crank shaft, as shown in Figs. 5 and 11. Instead of using a geared reduction, a silent chain belt is sometimes used.

Vertical motors are in common use with some types of pumps. They permit locating the pump at any depth below the motor. This may reduce or eliminate the suction lift and keeps the motor high and dry. The upper thrust bearing of the motor may be arranged to carry the entire weight on the vertical shaft if desired. If this is not done the motor drives through a flexible coupling. Vertical motors are available in squirrel-cage and wound-rotor types, and also in synchronous, brush-shifting and direct-current designs.

Some practical pointers on

Laying Out and Connecting A Pyramidal Winding

as used in three-phase induction motors, together with details of how to convert it to a two-layer diamond coil winding if necessary

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and
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ALTHOUGH largely used by only one nationally-known manufacturer of motors, the pyramidal type of winding is now frequently encountered by repair men who have little data on its construction and method of connection. The details given in this article will be of help in laying out this type of winding and thus make it unnecessary to use an equivalent two-layer diamond coil winding. Comparative details are given, however, for both windings so as to avoid mistakes when the pyramidal winding is used or converted to the two-layer winding. The pyramidal winding is not difficult to handle or understand and it is claimed that it aids ventilation and is an easy winding in which to locate shorts or opens.

IN THIS article details are given to aid the repair shop in laying out and connecting the pyramidal winding using form-wound coils. From Fig. 1 it will be noticed that the coils are arranged in three layers and that the winding resembles the concentric chain type of winding with the exception that the coils in each group are alike.

One advantage of this winding is that the pole-phase groups of coils are all alike in size and turns so that they can be wound as a unit on a gang mold. This saves considerable connecting time, as the soldering of connections between the individual coils in all the pole-phase groups is eliminated. The only leads from any group are the starting and the finishing leads. The number of coils per group determines the number of different sizes of molds or center blocks required for winding the coils.

A pole-phase group of form-wound pyramidal coils is shown in Fig. 2. The group in this case consists of two coils, the outside coil having one-half as many turns as the inside coil. This is due to the method of overlapping the pole-phase groups as will be explained later on. This type of winding is practically a combination of the basket and concentric chain types. The lower layers must be shaped as the coils leave the slots to allow the succeeding layers to clear the coil ends. The top or last layer, however, requires very little shaping.

This type of winding also has the advantage of requiring fewer coils to be handled than in the case of the two-layer diamond type. Combinations of poles, phases, and total number of slots are possible that result in a whole number of coils per pole per phase. The total number of coils required is one-half the number of slots. Where this combination results in a mixed number, as $1\frac{1}{2}$ coils per pole per phase, the total number of coils will be greater than one-half the number of slots. Examples of this will be given later. It is the number of poles, phases and slots combined that determines whether the pyramidal type of winding can be used, or whether a straight basket or two-layer lap winding will have to be used.

The long coil pitch necessary for two-pole motors, and other construction details, prevent the use of pyramidal type coils since the end windings would pile up. Anyone who has wound one of the old type Westinghouse CCL two-pole motors will understand why a two-layer winding is the best to use for two-pole motors, either two or three phase.

Other advantages claimed for the pyramidal winding are that ventilation is better as the coils are not nested together. Also, it is easier to locate and repair shorts, opens or grounds and a better opportunity is afforded to thread in a coil than is given in the case of the basket winding.

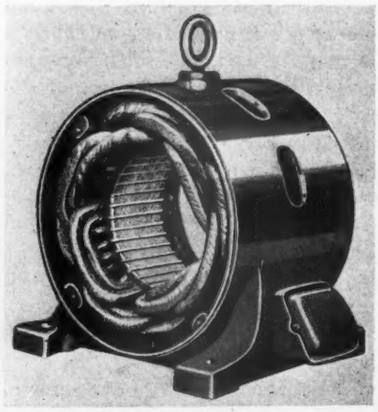


Fig. 1—How an induction motor stator looks when wound with form-wound pyramidal coils.
This is a $7\frac{1}{2}$-hp., 60-cycle, three-phase squirrel-cage induction motor stator having 36 slots and using 24 pyramidal coils.

The practical range of slots used in this type of winding is from 32 to 96. Thirty-two slots are used for four-pole, two-phase motors and the 96 slots for sixteen-pole, three-phase motors having 48 coils or one coil per pole per phase.

Table No. I gives type numbers of Century motors using pyramidal coils in four-pole, three-phase designs. This table gives the total number of slots and coils, the coils per pole per phase and also the maximum number of teeth spanned by the longest coil.

The winding shown in Fig. 1 is first on the list in Table I. This winding has 36 slots and 24 coils or $1\frac{1}{2}$ coils per pole per phase. This is figured as follows: for 36 slots and four poles, $36 \div 4 = 9$ slots per pole. Since this is a three-phase motor, $9 \div 3 = 3$ slots per pole per phase. In any one-coil-per-slot winding, the number of coils per pole per phase is equal to one-half the slots per pole per phase. In this case $3 \div 2 = 1\frac{1}{2}$ coils per pole per phase.

The total number of coils required equals the number of phases times number poles times coils per pole per phase. Then $3 \times 4 \times 1\frac{1}{2} = 18$. This would actually result in 18 full coils, but where we have $1\frac{1}{2}$ coils per pole per phase, we will also have an overlapping of coils. Thus, there

will be a number of coils with half as many turns as there are total turns per slot.

The number of half-coils is equal to the number of pole-phase groups, or in this case, 12. The number of full-turn coils is also equal to the number of pole-phase groups. We will then have 12 full-turn coils and 12 half-turn coils. To prove this, assume that there are 30 turns per slot. Then $12 \times 30 = 360$ turns for the full-turn and $12 \times 15 = 180$ for the twelve half-turn coils, or a total of 540 turns, and $540 \div 30 = 18$, which is the number of full-turn coils found by the formula given above.

The method of arranging the coils on the stator for 1½ coils per pole per phase is interesting. There are two ways of winding the 36-slot, four-pole, three-phase stator with 24 coils. The method shown in Fig. 1 will be explained first. As

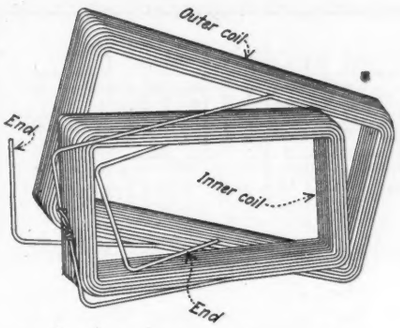


Fig. 2—A pole-phase group of form-wound pyramidal coils.
The outside coil has one-half as many turns as the inside coil.

can be seen in Fig. 1, the inside coil spans six slots, or its pitch is 1-and-7 which leaves five empty slots between its sides. The outside coil pitch is 1-and-9, or it spans eight slots.

In a chain winding the number of slots spanned by the inside coil depends on the slots per pole per phase, but in this type of winding the ratio of slots to coils determines the slots spanned and the overlap; or the number of slots minus the total number of coils equals the number of points of overlap. In the above case $36 - 24 = 12$, and since this is one-third the total number of slots, the overlap points will be spaced every third slot or slots *1, 4, 7,* etc.

To get the equivalent of 1½ coils per pole per phase, we can space the coil sides in four slots and allow the phase belts to overlap, or we can space the coil sides in three slots per pair of pole-phase groups and overlap the outside coils of like pole-phase groups. Fig. 1 shows the pair of pole-phase groups spread over four slots. With this method the inside coils overlap; hence the inside coils should only have half as many turns as the outside coils.

To start the winding, select a point on the stator that will bring the leads out to the best advantage and put in one pole-phase group. The inside coil in slots *3* and *9* of Fig. 3 and the outside coil of group *1* in Fig. 3 are in slots *2* and *10*. The next group, No. 2 of Fig. 3 is put in slots *11* and *19*, and *12* and *18;* the third group is in slots *20* and *28*, and *21* and *27*, and the fourth group of the bottom or A-phase layer is put in slots *29* and *1*, and *30* and *36*. The bottom layer now consists of eight coils in four groups and 16 slots. Since the inside coils are half-coils, we have eight full slots and eight half-full slots. The full slots are adjacent in groups of two, as slots *1* and *2*, *10* and *11*, *19* and *20*, and *28* and *29*. The slots on either side of, and adjacent to, these are half full.

The second or B-phase layer starts in a half-full slot, or the inside coil of group *5* starts in slot *9*, the other side being placed in slot *15*. The outside coil of group *5* is put in slots *8* and *16*. The next group, *6*, is put in slots *17* and *25*, and *18* and *24*. Group *7* is in slots *26* and *34*, and *27* and *33*, and group *8*, which is the last group of the second or B layer, is in slots *35* and *7*, and *36* and *6*. With these two layers in place, slots *1, 2, 7, 8, 10, 11, 16, 17, 19, 20, 25, 26, 28, 29, 34* and *35* are filled with full-turn coils.

Slots *9, 18, 27* and *36* are also filled by the overlapping of the half-turn inside coils of the A- and B-phase layers. Slots *3, 6, 12, 15, 21, 24, 30* and *33* are half full, and slots *4, 5, 13, 14, 22, 23, 31* and *32* are empty and these slots locate the out-

Tables I, II and III—Details of Pyramidal-Type Windings Used in Century Motors

Table I—Motor Type, 3-Phase, 4-Pole	Max. Teeth Embraced per Pole	Coils per Phase	Number Slots	Number Coils
SCI –SCIL–ASI½	9	1½	36	24
SCI½–SC3 –AS3	9	1½	36	24
AS6B–SC4 –AS5B	9	1½	36	24
AS6C–SC5 –AS6	9	1½	36	24
SC8B–SC8 –AS8	11	2	48	24
SCI3–ASI3	11	2	48	24
SC15–AS15	11	2	48	24
SC19–AS19–AS18	17	3	72	36
AS25L	17	3	72	36
AS30	17	3	72	36
AS35	17	3	72	36
AS40	17	3	72	36
Table II—Motor Type, 3-Phase, 6-Pole				
SCI–SCIL–SCI½B–SCIB	5	1	36	18
SC3–SC4 –SC5 –AS3	5	1	36	18
AS6B–AS6C –AS6	5	1	36	18
SC8B–SC8 –AS8	5	1	36	18
SC13 –AS13	9	1½	48	*
SC15 –AS15	9	1½	48	*
SC19–AS19 –AS18	11	2	72	36
AS26L–AS25L	11	2	72	36
AS30	11	2	72	36
AS35	11	2	72	36
AS40	11	2	72	36
Table 3—Motor Type, 3-Phase, 8-Pole				
SCI½–SC3 –AS5B–AS6B	5	1	48	24
SC4 –SC5 –AS6 –AS6C	5	1	48	24
SC8B–SC8 –AS8	5	1	48	24
SC13 –AS13	5	1	48	24
SC15 –AS15	5	1	48	24
SC19 –AS19–AS18	9	1½	72	48
AS26L–AS25L	9	1½	72	48
AS30	9	1½	72	48
AS35	9	1½	72	48
AS40	9	1½	72	48

* Basket winding used.

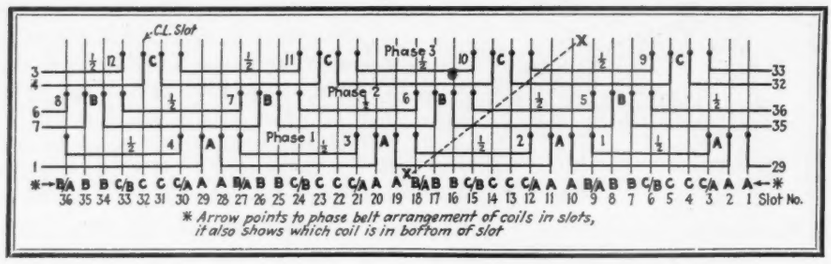

C.L. Slot
Phase 3
Phase 2
Phase 1
X
X'
Slot No.
* Arrow points to phase belt arrangement of coils in slots, it also shows which coil is in bottom of slot

Fig. 3—Layout of a pyramidal winding for a four-pole, three-phase stator having 36 slots and 24 coils with 12 full-turn inside coils and 12 half-turn outside coils, or 1½ coils per pole per phase, with short coil pitch.

side coil sides of the third or C-phase layer. The outside coil of group *9* is put in slots *5* and *13*, and the inside coil in slots *6* and *12*. Group *10* is in slots *14* and *22*, and *15* and *21*; group *11* is in slots *23* and *31*, and *24* and *30*. The twelfth and last group is in slots *32* and *4*, and *33* and *3*.

The 24 coils and 12 groups are now all in place and the letters at the bottom of Fig. 3 show the arrangement of the phases. For example, slots *1* and *2* are used totally by A-phase coils, while in slot *3* the coil in the bottom of the slot is from the A phase and the top half from the C phase or the C and A phase belts overlap in this slot. The phase belts also overlap in slots *6*, *9*, *12*, *13*, *18*, *21*, *24*, *27*, *30*, *33* and *36*, and the letter in the bottom indicates the position of the coil in each slot.

The one advantage of this arrangement of coils for 1½ coils per pole per phase is that for machines having a small number of poles, such as four, the coil pitch is shorter and thus less copper is used.

Figs. 4, 5 and 6 show the type of winding and connecting diagram that can be used to convey the necessary information for winding and connecting these motors. The vertical and horizontal lines will aid in locating the slots with reference to the line lead position. This diagram locates the pole-phase groups with reference to center lines. It also gives the proper coil pitches and the arrangement per pole per phase. This type of diagram can be used for any four-pole, three-phase, 36-slot stator with 1½ coils per pole per phase with short coil pitch, regardless of the turns per coil and the size of wire.

In these diagrams the two-in-and-one-out arrow check can be used. A separate diagram is used (Figs. 4, 5 and 6) to show each phase layout; the letters *A* indicate the line leads, as T_1 (Fig. 4), T_2 (Fig. 5), T_3 (Fig. 6). *D* is the star connection; *B* indicates the end of the first series of groups of coils equal to one-half the total groups per phase. *C* indicates the start of the second series of groups. These notations can be used to give instructions for a two-parallel star connection. The sketches in Figs. 4, 5 and 6 show a series-star connection. To change to two-parallel star, open the jumper *B-C* and connect the *B* end to the star or *D* and the *C* end to *A*. Repeat this for each phase.

Figs. 4, 5 and 6—Winding and connecting diagrams for each phase of a four-pole, three-phase stator with 36 slots.

These diagrams locate the pole-phase groups with reference to the center lines and give the proper coil pitches and arrangements per pole per phase. Short coil pitch is shown.

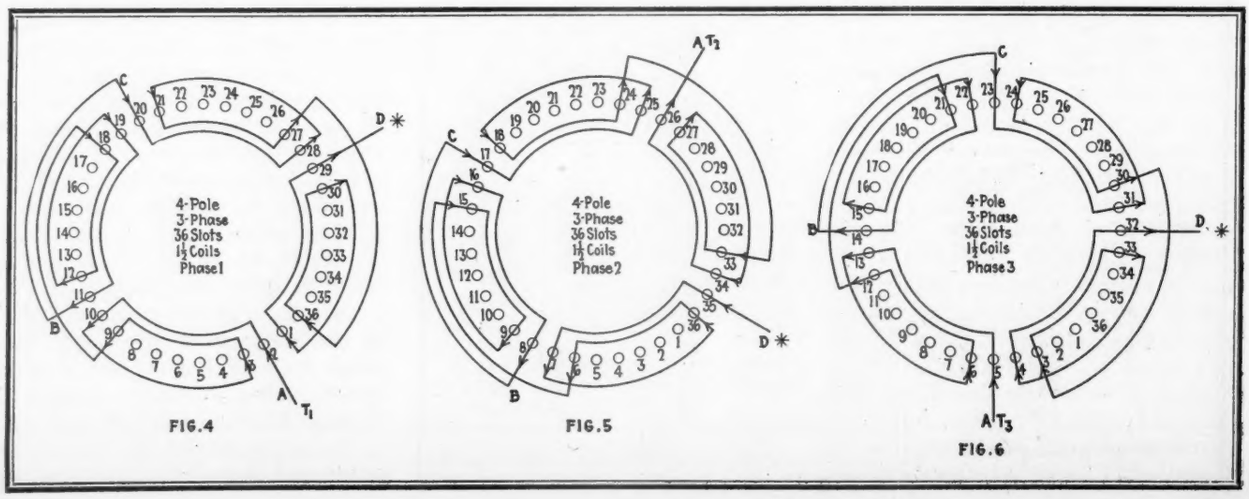
Studying Figs. 3, 4, 5 and 6 it will be found that the inside or small coils overlap in slots *3*, *6*, *9*, *12*, etc., and that the mechanical arrangement of the coils is in four slots per pole per phase. Also, due to the overlap, the electrical arrangement is equal to 1½ coils per pole per phase. These sketches will also show that with 1½ coils per pole per phase and short coil pitch all inside coils must have half as many turns as the outside coils.

The dotted line *x-x* in Fig. 3 shows how this type of winding gets the name pyramidal. Also Fig. 1 shows how the coils are arranged in pyramidal form, or are wound on the stator in three layers or ranges.

Figs. 7, 8, 9 and 10 show the long coil pitch method of winding the four-pole, three-phase, 36-slot, 24-coil stator with 1½ coils per pole per phase. This method results in a balanced arrangement, both electrically and mechanically, of three slots per pole per phase and 1½ coils per pole per phase without the overlapping of phase belts.

With this arrangement the outer coils all have half as many turns as the inner or small coils. The inner coils span seven slots or the pitch is 1-and-8. The pitch of the outer coil is 1-and-10, or nine slots are spanned. The span of the small coil leaves six unused slots between the coil sides. The span of the large or outer coil results in these coils overlapping but only adjacent groups of the same phase overlap.

In Fig. 7 the first coil of group *1* is put in slots *1* and *8*, and the next coil in slots *36* and *9*. These last two slots are only half full after putting



in the second coil. Next, the inner coil of group *2* is put in slots *10* and *17*, filling both. The outer coil of group *2* is put in slots *9* and *18*, filling slot *9* and half filling slot *18*. Next, the inner coil of group *3* is put in slots *19* and *26* filling both, and the outer coil of group *3* is put in slots *18* and *27*, resulting in slot *18* being full and slot *27* half full. The inner coil of group *4* is started in slots *28* and *35;* then the outer coil of group *4* is put in slots *27* and *36*, both of which were half full. Thus the last coil of group *4* fills slots *27* and *36* and ends the first or A-phase layer of coils, filling slots *35-36-1, 8-9-10, 17-18-19* and *26-27-28*.

The second or B-phase layer is started by putting the inner coil of group *5* in slots *4* and *11*, filling these, and the outer coil in slots *3* and *12*, half filling these. Next, the inner coil of group *6* is put in slots *13* and *20*, filling both, and the outer coil in slots *12* and *21*, filling slot *12* since the outer coil of group *5* and *6* overlaps in this slot and slot *21* is half full. Next the inner coil of group *7* is put in slots *22* and *29*, filling both, and the outer coil in slots *21* and *30*. Slot *21* is now filled and slot *30* half filled. The inner coil of group *8* is then put in slots *31* and *2*, filling both, while the outer coil of group *8* goes in slots *30* and *3*, overlapping the outer coils of groups *5* and *7*, thus filling slots *30* and *3* and ending the second or B-phase layer.

We now have 16 coils in place in two layers, with slots *8-9-10-11-12-13, 17-18-19-20-21-22, 26-27-28-29-30-31* and *35-36-1-2-3-4* all filled, and slots *5-6-7, 14-15-16, 23-24-25* and *32-33-34* empty. These slots are used for the third or C-phase layer which starts with the inner coil of group *9* in slots *16* and *23*, filling both, and the outer coil in slots *15* and *24*, leaving both half filled. The inner coil of group *10* is put in slots *25* and *32*, filling them, and the outer coil in slots *24* and *33*, filling slot *24* by the overlapping of the outer coils of groups *9* and *10*. Slot *33* is now half full. Next the inner coil of group *11* is placed in slots *34* and *5*, filling both, and the outer coil is put in slots *33* and *6*, filling slot *6*. The inner coil of group *12* goes in slots *7* and *14*, filling both, and the outer coils in slots *6* and *15*. This ends the third layer and the winding, by filling these last two slots, or the last coil in overlaps the outer coils of groups *9* and *11*.

The horizontal row of letters *A*, *B* and *C* at the bottom of Fig. 7 shows the arrrangement of the phase belts and also indicates how the half-turn outer coils overlap. Figs. 8, 9 and 10 give a connecting and coil layout diagram for each phase.

This long-pitch method is easier to apply than the short pitch and the winding is also easier to insulate, as the pole-phase groups do not overlap in the slot sections.

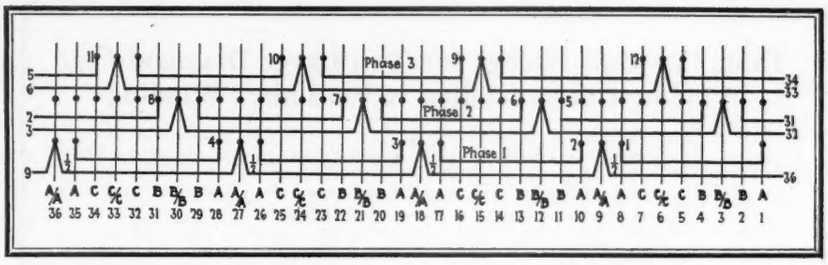


Fig. 7—Layout of pyramidal winding for same stator as in Fig. 3, using long coil pitch without overlapping of phase belts.

Figs. 8, 9 and 10—Winding and connecting diagrams for each phase of the winding shown in Fig. 7.

The ends of all coils in pyramidal-type windings should be taped with one layer of half-lapped treated cloth and one layer of half-lapped cotton tape and the complete winding preheated, dipped and baked. Single or double-cotton-covered and enameled wire can be used for the coils.

In Fig. 11, *A*, *B*, *C* and *D* show the winding and connecting diagrams for a four-pole, three-phase, 48-slot stator having 24 coils, or two coils per pole per phase and four slots per pole per phase. Diagram *A* in Fig. 11 shows that the first group of phase 1 or A starts with the inner coil in slots *2* and *11*, and the outer coil in slots *1* and *12*. All four slots are filled, as with a whole number 2, 3, 4, etc., of coils per pole per phase, each coil of the group has the same number of turns and the pole-phase groups do not overlap. A study of diagrams *A*, *B*, *C* and *D* in Fig. 11 will show how the coils are wound in place and connected up.

Table I also shows a 72-slot, four-pole, three-phase, motor frame. This will have 36 full-turn coils arranged in pole-phase groups of three, or there will be 12 groups, three coils per pole per phase and six slots per pole per phase. The pole-phase groups will not overlap, the coil pitches being 1-and-18 for the outside coils, 1-and-16 for the middle coils, and 1-and-14 for the inside or small coil. There must be 12 unused slots between the coil sides of the

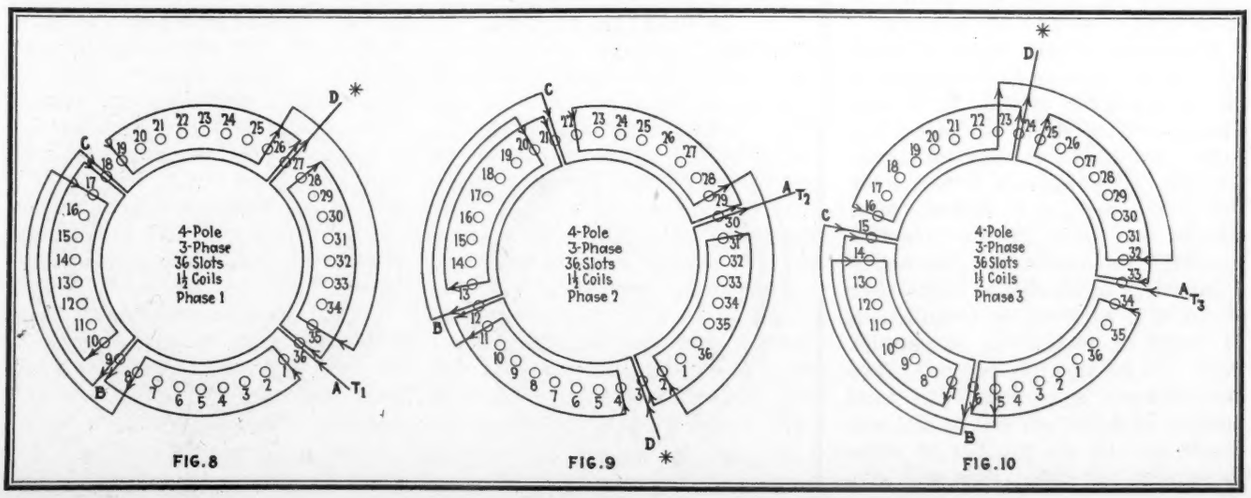


FIG. 8 FIG. 9 FIG. 10

Table IV—Coil Pitches for Two-Layer Diamond Coil Winding Corresponding to Pyramidal Winding

Poles	Slots	Coils	Coil Pitch	Average Pitch
4	36	24	1–7 1–9*	1–8
4	36	24	1–8 1–10**	1–9
4	48	24	1–10 1–12	1–11
4	72	36	1–14 1–16 1–18	1–16
6	36	18	1–6	1–6
6	72	36	1–10 1–12	1–11
8	48	24	1–6	1–6
8	72	48	1–7 1–9*	1–8
8	72	48	1–8 1–10**	1–9

* Short coil pitch winding.
** Long coil pitch winding.

inner or small coil of each pole-phase group.

Table II gives the number of slots, total number of coils, etc., and the arrangement of coils for six-pole, three-phase windings. For 48 slots and six poles, three phase, the winding will be of the basket type, with odd grouping. With 72 slots, six poles, three phase, there will be 36 full-turn coils, arranged in 18 groups of two coils per group. The inside coil pitch will be 1-and-10 and the outside coil pitch 1-and-12.

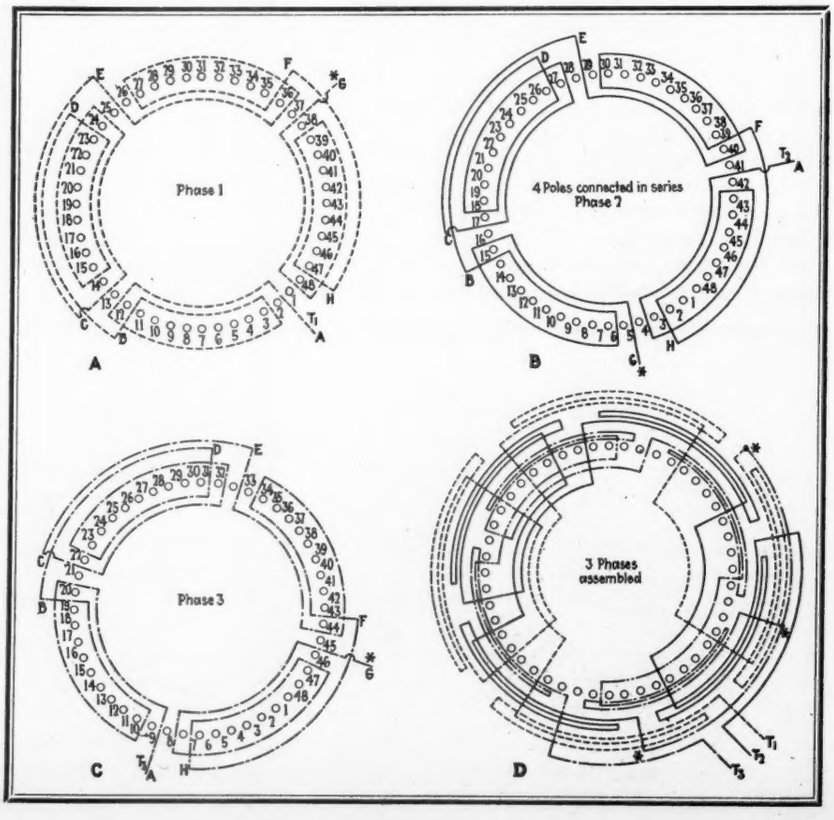
Table III shows the number of slots, coils and the arrangement for eight-pole, three-phase stators. The 48-slot, 24 full-turn coil, eight-pole winding has 24 groups, with one coil per group. The 72-slot, eight-pole, three-phase winding will have 48 coils arranged in 24 groups of two coils per group, with the inside or outside coils overlapping as in the 36-slot, 24-coil, four-pole, three-phase winding already described and shown in Figs. 3 to 10.

For those who want to change the pyramidal to the more familiar two-layer diamond coil type of winding, the following data will give the correct turns per phase, pitch, etc., to be secured from the old winding.

The first step is to count the total number of slots in the stator and the total number of coils in the old winding. Then when stripping the stator, check the number of turns per coil, or the number of turns per slot. The object is to find the total number of turns in the complete winding. Care must be taken not to count wires in parallel as turns. For example, if each coil is wound with 24 turns of two wires in parallel, there will be 48 wires per coil. The best method is to count the total number of wires per coil or slot and divide this by the number of wires in parallel per coil. This will give the turns per coil. At the same time check the pitch of the coils, inner, middle and outer, and put this down as 1-and-10, 1-and-13, etc.

Total turns per motor are equal to one-half the number of slots times the turns per slot, or the number of coils times the turns per coil. For the two-layer winding there will be as many coils as slots and the turns per coil are equal to the total turns per motor in the old winding divided by the number of slots.

Fig. 11—Winding and connecting diagrams for a four-pole, three-phase stator having 48 slots and 24 coils or two coils per pole per phase and four slots per pole per phase.



The coil pitch for the new winding will be the average pitch of the old winding and is found by expressing the pitch in slots spanned by each coil in the group, adding the pitches of all coils in one pole-phase group and dividing the total by the number of coils per group. This has been done in Table IV.

The following example will explain how this is done. Consider the 72-slot, 36-coil, three-phase, four-pole winding. This has three coils per pole-phase group, the pitch of the inner coil being 1-and-14, or 13 slots spanned; the middle coil pitch is 1-and-16, or 15 slots spanned, and the outer coil pitch is 1-and-18, or 17 slots spanned. Then $13 + 15 + 17 = 45$ and since there are three coils per group, the average pitch in slots spanned is $45 \div 3 = 15$, or 1-and-16 will be the coil pitch of the two-layer winding. The size of wire should be kept the same for both windings.

Operating conditions will determine whether all the coil ends of the two-layer winding need to be taped. If all coils are taped, a single half-lapped layer of cotton tape on each coil end will be sufficient. Treated cloth tape is not necessary with the two-layer winding since the difference of potential between adjacent coils is lower, being approximately one-half that of the old type.

We Do Not Read Enough or Well Enough

Most of us have this fault which, along with some others of like nature, can be easily corrected

Seven Sage Counsels

By Glenn Frank

For years H. L. Mencken has been flogging the south with his critical cat-o-nine-tails as the Sahara desert of living thought and the fine arts.

If the south were as much a field of charred stubble as Mr. Mencken contends, even he would have to admit that many fresh sproutings of new vitality are thrusting their way up through the stubble.

There has just come to my desk an interesting volume on "The Advancing South," by Edward Mims. It presents a fascinating story of fresh stirrings in the church, in politics, in the press, in literature, and in education in the south.

I have not yet read this volume carefully, but as I write, it lies before me and my eye lights upon a reference to one of South Carolina's contagiously alive scholars—Howard W. Odum.

Mr. Mims says of him: "Odum is as bad as Matthew Arnold in asking the most uncomfortable questions without necessarily answering them himself, but leaving the intelligent reader to give his own answers.

Such minds are priceless, for, after all, it is not the business of a teacher to be comforting, but to be disturbing; it is not the business of a teacher to put something into his hearers' heads, but to start something in their heads.

In the spring of 1924, Mr. Odum made an address at his alma mater, Emery university. He was speaking not to Georgia only, but to the whole south. He gave seven sage counsels. And I suggest that he might, with equal point, have addressed these seven counsels to the whole American people. Here they are:

"We do not know enough.
"We do not think enough or well enough.
"We do not read enough or well enough.
"We do not write enough or well enough.
"We do not do enough or well enough.
"We do not work together well enough."
"We talk too much."

The individual, the state, or the nation that does not take to heart these seven counsels will inevitably become the tool of "the demagogues and the dogmatists in politics and religion."

We must know more. There is enough knowledge lying unused in our laboratories and libraries and in the minds of the creative pioneers in politics, industry, religion, education, and science to lift the whole tone and temper of American life. It is the business of statesmanship, official and unofficial, to get this knowledge out into the open, thrust it into the stream of common thought, and make it the basis of our common life.

We must think more and read more and learn better how to put into clear and simple speech the fruits of our thought and reading. Our scholars and writers can help us here. We must breed more scholars and writers who combine the burrowing qualities of the mole with the singing qualities of the lark, men who are masters alike of the science of research and the art of expression. Too much of our knowledge has not got beyond the stage of inarticulate accuracy.

All seven of these counsels will repay careful pondering.

(Copyright for The Omaha Daily News.)

THE other day I found the clipping shown on this page in a daily newspaper. It set me to thinking. I wish you would read it and think a little, too, for this item contains wisdom of a rare sort. First of all, it comes from the pen of a young man, Glenn Frank, who has pulled himself up by his own efforts and mental ability to one of the highest positions in the educational world, that of President of the University of Wisconsin. Already he is well known as a lecturer and writer, and crowds of men twice his age show him the respect that knowledge of a subject merits from any man.

Glenn Frank calls attention among other things to the fact that we do not know enough, we do not think enough, or well enough, and we do not read enough, or well enough. This is certainly a bold comment, but it's true and if you are honest with yourself you will admit it. Having admitted it, you have found the reason why you are just where you are, if you are not satisfied with your success, your salary, or your job.

In the field of plant operation there is today a burning need for men who know much more than their fellow workmen; for men who possess originality, initiative and think things out by themselves. Anybody can follow the crowd, imitate the other fellow, and through years of experience learn to do a first-class job; but the fellow who is a leader must be a thinker—as well as a doer. He must read and read, to advance his own thinking.

When we started INDUSTRIAL ENGINEER more than four years ago the main editorial idea was to provide a paper for thinkers—plant operators who desire some day to be plant managers, if not plant owners. And this aim has never been abandoned. This publication has helped operators to know more—they have not only told us so but they have demonstrated it by contributing to the discussions on plant problems that appear in each issue. And their names do not appear in one issue only—they continue to appear. They are thinking more and better. They are reading more and better, and they are writing more and better. If they keep this up they are certain to know more and get a better job.

If your name has not appeared in the pages of INDUSTRIAL ENGINEER and stamped you as a thinker, then it's your own fault. The Question and Answer department invites you to take a hand in answering the problems that appear each month. How do you know but that your boss reads the answers to these questions, to locate a man for a good job he has in mind? Think a little right here and let us hear from you and put your name down in cold type as one who knows what he knows, but is ready to admit that he still does not know enough. Let's create a "We Want to Know" club and use the Question and Answer section of INDUSTRIAL ENGINEER more frequently as the means for getting the answer.

Practical Pete

INDUSTRIAL ENGINEER
Devoted to the Maintenance and Operation of Electrical and Associated Mechanical Systems in Mills and Factories
G. A. VAN BRUNT, *Managing Editor*

Electrical Accidents Cause Far More Than Their Share of Losses

PROOF of the necessity of securing full co-operation between the electrical engineer and the safety engineer was given by Charles B. Scott, President of the National Safety Council at the annual convention of the Association of Iron & Steel Electrical Engineers held last month at Chicago.

Mr. Scott said that from an analysis of some 12,000 accidents occurring during a period of years among the 50,000 employees coming under the supervision of the Bureau of Safety of which he is Director, only 8 per cent of the total accidents were caused by electric current. However, this 8 per cent of the total accidents was responsible for 75 per cent of the total accident costs, for slightly more than 75 per cent of the total lost time, and for 75 per cent of the fatalities that occurred as a result of accidents.

These data show the importance of concentrating effort in reducing electrical hazards. This is being done in many plants. The next step is to secure better co-operation among the operating men and maintenance men connected with the operation of electrical equipment. Such co-operation can best be secured by careful selection of the men who are to do the work, careful instruction of the men on how the work is to be done and last, but most important, is constant, careful, and close supervision of the men in all matters regarding safe operation of the equipment they control.

Let the Spirit of Competition Help to Set New Records

THE desire to play, and to engage in friendly competition with our fellow men, is a very natural and deep-seated instinct whose value is greater than is oftentimes realized. For one thing, it induces us to seek that change of viewpoint and relaxation from our every-day work that keeps us interested and prevents us from going "stale" mentally. In keeping with this idea, we invent all sorts of games and contests and deliberately increase the difficulty of playing and winning them by imposing various rules which must be followed, even though there is no prize at stake.

In reality the chief purpose of these rules is to lessen our chances of winning. To the average person there is no fun in winning too easily; most of us would rather play a game that makes us exert ourselves to the limit.

This inherent love of a contest can be, and frequently is, utilized to good advantage in the conduct of business. It has been found times without number that if two or more departments or groups of men can be induced to enter into competition with each other, the morale of the men is heightened at once and noticeable progress is made toward securing increased output, a reduction in the number of accidents, or whatever else may be desired.

Naturally, any movement will be more successful if the men are given some incentive in the way of a bonus or reward, and this is usually necessary in order to sustain interest over a long period of time. Nevertheless, surprising results can oftentimes be secured when no reward is at stake, merely by arousing the spirit of competition in some effective manner.

Any executive who does not recognize and make use of this spirit in his men is overlooking a very potent force which may be a decisive factor in his own success, as well as that of his department. To arouse this force and keep it active calls for leadership and a keen sense of fair play which will see that honest effort is suitably recognized. Granting these qualifications, it is not a difficult matter to awaken in the personnel of any department, or of the entire plant, a friendly rivalry that may produce surprising results.

Are You Taking Advantage of the Progress Made in Maintenance Practice?

"ONE of the most thriving industries in any country is thinking up reasons why a new thing can't be done. That is the root of England's economic difficulty today. They've kept the old equipment so long that they can neither pay wages nor make profits on their capital. The question is not how long you can keep a thing, but how quickly you can economically scrap it. That's progress."

In these words, Owen D. Young, Chairman of the Board of Directors of the General Electric Co., states the necessity for progress. Such progress is, however, not confined to electrification of steam railroads, use of larger generating units in power houses, and similar large projects, but is also present in the commonplace but very essential work of maintaining equipment so as to keep it in continuous operation.

For instance, a few years ago it was necessary to remove rivets with a sledge and cold chisel, and pieces of shafting were sawed in two with hacksaws before replacements or repairs could be made. The oxyacetylene torch, arc welder, electric drill, air hammer and other portable tools have changed this procedure and are earning big money for those who make use of them. Sparking of commutators was thought to be a necessary evil and commutators were greased, turned, and in general had a short life until the full realization of the necessity for proper application of brushes suited to the individual characteristics of the motor or generator. Many plants have found that ball and roller bearings are able to effect maintenance savings that make them a decidedly good investment. Improved lubrication by high-pressure systems, filtering forced feed systems,

and so on, are helping to increase the life of bearings. Last, but not least, is the change in policy of the maintenance department. Instead of the "wait-until-it-breaks" attitude we find a "fix-it-first" policy in operation, with the result that operating costs and delays are being reduced.

Thinking of reasons why improved maintenance tools and methods are not required in a particular plant will never aid that plant to reduce its operating costs. Results obtained in the more progressive plants point the way in scrapping obsolete maintenance equipment and methods. At least follow the leaders if you can't set the pace.

You Can Save Trouble Later On By Overhauling Equipment Now

IN MANY lines of industry there is a more or less definite slackening of production during the summer months. This let-up affords an opportunity, which is taken advantage of in many industrial plants, to go over all of the equipment and make whatever repairs or replacements are necessary to put it in proper operating condition. In too many cases, however, such work is done only on equipment that is obviously in need of repairs; if a piece of equipment does not show any defects on a casual inspection, it is given no further attention.

This practice is all right as far as it goes, but it does not go far enough. The natural wear and tear of service give rise to many little weaknesses that are not always visible or easily detected, but which will eventually lead to trouble if neglected. Bearings become worn, windings acquire a coating of oil and dirt, contacts on control equipment become rough and pitted, and so on through a long list of defects and abnormal conditions that develop in both the electrical and mechanical elements of power drives and should not be allowed to go uncorrected.

It is a good plan to give all power drive equipment a thorough overhauling at least once a year, and oftener if possible, or if the equipment is unusually important. Thus, motors should be taken down, the windings tested, cleaned and painted, bearings checked up and replaced if necessary, and everything put into perfect condition. In the same way, control equipment and protective devices should be carefully examined and tested. Periodic checking of lineshafts for alignment will often disclose conditions that should be remedied. Belt, chain and gear drives may likewise well come in for their share of attention, as they frequently do not receive the care that they need. Now is also a good time to make any necessary changes or additions to the plant lighting system.

When properly scheduled and handled, the expense of overhauling equipment is not so great as it is sometimes considered to be. In any event, it is an effective means of reducing repair costs and preventing production delays later on when equipment must be worked to the limit.

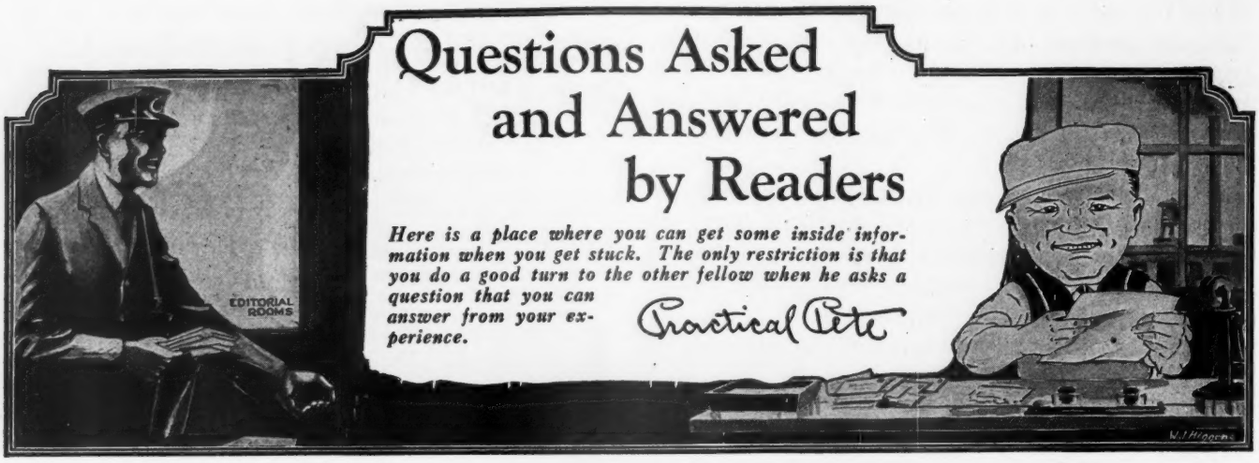
Supervision Is an Expenditure That Bears Watching

MR. GEORGE F. JOHNSON, President of Endicott-Johnson & Co., shoe manufacturers, commented in a recent article on the cost of supervision in manufacturing plants and business operations in general, and stated that the most effective way to cut costs is through cutting down the cost of supervision. He was very blunt, in his remarks on this subject, in pointing out that the all-too-common belief is that if you put a man to work at a job, it is necessary to put another over him to see that he does it and then a third man to keep a record of what is done. The result of this, he thinks, is the growing of a race of workers who are afraid of responsibility and afraid of thinking out their own tasks, and want to be supervised and directed in the most minute detail.

There is much truth in this opinion. Take responsibility for accuracy, results, or quantity of production, away from an individual and you have destroyed his initiative; and when initiative is destroyed individual thinking is replaced with mechanical movements which machines can perform with greater accuracy. In a plant where there is little opportunity for individual thinking, or a reward for it when it is of an unusual order, there is sure to be discontent; and there is no one thing that saps interest in what a man is doing like being unhappy at his work. Single out the men who whistle while they work and train these men for responsibility; more will come from your efforts than from twice as many men working in a disgruntled frame of mind.

This is no pearl of wisdom: it is an observation that any one who understands himself knows to be a plain matter of fact. The hopes, desires and ambitions of a man who works with his hands are not so different in kind from those of the man who works with his brain. Unnecessary supervision and subjection to a set level of thinking established by such supervision not only kills initiative in men but invites them to repeatedly commit errors that may not be caught until much loss has resulted in waiting for the error to reach the inspector or supervisor. Then to fire the man who committed the error is not the cure, for another man in the same position will soon, in all probability, fall into the same frame of mind toward his work.

When more leaders of industry are forced to study their production costs down deeper than the cost figures furnished to them by their supervisors, then we will find a way out of the situation that now calls for such frequent reference to labor costs as being excessive. Efficiency forced by supervision calls for an expenditure that cannot long be passed on to the ultimate user of the product made, or the service used. If you are a supervisor of men think about this and study human nature as well as the mechanical problems with which you may be forced to deal. You will learn many things that you can use to good advantage.



Questions Asked and Answered by Readers

Here is a place where you can get some inside information when you get stuck. The only restriction is that you do a good turn to the other fellow when he asks a question that you can answer from your experience.

Practical Pete

Who Can Answer These?

Changing Speed of Universal Motors — Is there any way that the speed of a universal motor can be changed when rewinding? I shall greatly appreciate any information that readers can give me on this question.
Los Angeles, California. H. K.

* * * *

Burned Spots on Collector Rings—We are having considerable trouble from burned spots on the collector rings of the field of a 300-kva., three-phase, 240-volt, 25-cycle alternator. These spots are about the size of the brush faces and I am at a loss as to what may cause them. Can any readers tell me causes for this trouble and also suggest remedies for it. I shall be grateful for any information that readers can give me.
Petersburg, Va. J. W.

* * * *

Removing Flange Couplings from Shaft—Have any of our readers had experience in using an acetylene welding or cutting torch for heating and loosening solid flange couplings to facilitate their removal from shafts? If so, what type of flame should be used? Also, may tight gears and solid-hub pulleys be removed in the same way? Is there any danger of warping or distortion, due to the heating, so that the gears or pulleys will not operate satisfactorily when replaced? Should there be any difference in the treatment of steel and cast-iron hubs?
East St. Louis, Ill. M. M.

* * * *

Substitute for Crane Collector Bars—We are having considerable trouble with the collector bars on a floor-type charging crane used for charging skelp into a heating furnace. These collector bars are placed below the floor level and are reached by a collector rigging operating through a slot in the floor. We propose to do away with this method, because of maintenance troubles, and substitute a multi-conductor cable which will run from the crane to some fixed point nearby. Can some reader tell me how to rig up a device for retrieving this cable so as to prevent it from being dragged over the floor or catching on objects placed on the floor? The total travel of the crane is about 25 ft. and the cable must not be carried higher than 10 ft. in the air for there are cranes working overhead that might interfere with the cable.
Gary, Ind. F. U.

* * * *

Cause of Heating of Fuse Studs—What causes heating of fuses and studs on our switchboard panel, which is built for three-phase, four-wire distribution? The studs and fuses, which are standard make and rated at 600 amp., heat to the danger point and three fuses have been blown at a load of only 400 amp. The panel on which the studs are mounted is of slate and the spacing and carrying capacity of studs and busbars is more than the Code requires. We have aligned the studs and fuses so closely that a piece of flat steel .001 in. in thickness cannot be pushed in at any point between the clips and fuses. Suspecting loose contacts to be causing the heat, we have used wood clamps on the fuses and clips with no result. Reducing the load from 400 amp. to 200 amp. does not lower the temperature to a point permitting the hand to be placed on the fuse clips. There are no iron washers on the studs and renewable fuses of standard and reliable manufacture are in use. The neutral fuse, however, does not heat. Our voltage is 220 volts across the phases and 127 volts from neutral to any phase. Can this heating be caused by mineral veins in the slate panel? It is impossible to feel any current in the slate by wetting the hands and placing them on the slate. The heated area does not extend back more than 10 in. from the fuse studs and does not reach the main bus which is composed of two 3-in. x ¼-in. busbars. I shall appreciate your help on the problem.
Elgin, Ill. A. B. A.

* * * *

Testing Fuses to Prevent Motors Running Single-Phase—We have a large number of three-phase induction motors that are protected by individual fuses placed near each motor. Also, the different branch circuits feeding several motors are protected by fuses. To insure that the motors do not operate single-phase, frequent tests are made of the fuses. Is it sufficient to test the fuses by temporarily connecting a lamp of suitable voltage across the ends of each individual fuse? Will a lamp test across the phase wires ahead of or after the fuses give a positive indication? Will connecting the lamp ahead of one fuse and behind the adjacent fuse give a reliable indication? I should like to have some of the readers discuss these questions for me and point out which is the best method to use for testing under the conditions described and also tell how to interpret the different indications obtained from the lamp.
Newark, N. J. W. S.

* * * *

Lightning Protection for Short Overhead Power Line.—We have a 3,300-volt two-phase, 25-cycle, 80-amp. transmission line running a distance of 1,080 meters from our substation to the mouth of our copper mine. At the shaft, this line is spliced to a lead-sheath cable which goes down the shaft a distance of 200 meters where it is connected to a switchboard that supplies other feeders radiating through the mine. The wire and cable used for this transmission line are No. 00 B. & S. gage. The elevation of the country through which the line runs is approximately 4,100 meters above sea level. As the overhead line must have good lightning protection, I wish to install choke coils and lightning arresters at both ends of the line, but I have heard that choke coils should not be installed in connection with lead-sheath cables. Why is this? Won't some reader tell me how to protect this overhead line against lightning? We now have an oxide film arrester at the substation and a compression chamber multi-gap arrester at the shaft mouth, where the overhead line is connected to the lead-sheath cable. Is this sufficient protection? Should I not use choke coils both at the mine mouth and at the substation? What lightning protection would readers recommend for this transmission line?
Pulacayo, Bolivia. C. L. C.

Answers Received To Questions Asked

Method of Checking Bearing Alignment.—I should like to know how to check the alignment of bearings on machines having three or more bearings supporting the same shaft, or where two shafts are coupled together by means of rigid couplings. An example of this is a three-bearing, motor-generator set or a large, heavy-duty motor or pump having a pedestal bearing in addition to two regular bearings. I shall appreciate any suggestions that readers can give me for doing this work.
Chicago, Ill. F. B.

Referring to F. B.'s question regarding the checking of bearings, the following suggestions are offered. Assuming that the motor bedplate is level, all that is required is a straight-edge and a level. If the shaft is reduced in diameter at either or both ends, the main bearings (those supporting the largest diameter of shaft) should be checked first. To do this, the bearing caps should be removed and the straight-edge and level placed in the bottom center of the bearing. If both pedestals are not level, one of them should be shimmed, providing the bedplate does not require leveling. Next, check up the third pedestal; if the shaft is smaller in this bearing, the radius of both shaft sizes should be taken and the difference between them added to the height at which the pedestal should be set. The straight-edge should be placed in the main bearings and the distance measured to the bottom of the third bearing.

A quicker method of checking the alignment is to use a plumb line through the centers of all the bearings, shimming each individual bearing until they have a common and level center.

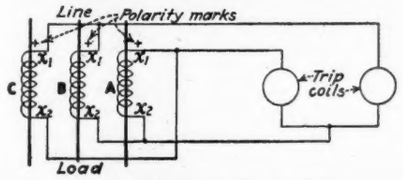
However, care must be taken in using this method, as it is very easy to shift the line. After all the bearings are lined up, the pedestals may be removed and the rotor put in place. The air-gap between the rotor and stator should then be checked with a feeler; if the rotor is not properly centered, the stator should be shimmed up or shims removed, as the case may be. The bearing pedestals should not be raised or lowered to center the rotor. After the motor is completely assembled, the shaft in each bearing should be checked with a shaft level before the bearing caps are replaced.

If the shaft is in two or more sections and connected with either rigid or flexible couplings, the main section should be lined up first. This can be done by either a straight-edge or a dummy shaft. The next section of the shaft should then be put in and leveled to the height of the first section, bringing the two halves of the coupling together, so that they are of the same height and the same distance apart on all sides. A feeler can be used to check this point. When both sections of the shaft are level and the two halves of the coupling butt perfectly, they may be bolted together without fear of springing the shaft.

Electrical Engineer, H. E. STAFFORD.
Provincial Paper Mills, Ltd.,
Port Arthur, Ont., Can.

* * * *

Is This Relay Connection Scheme Correct? —I have a 300-hp., three-phase, 60-cycle induction motor that is star-connected to a 4,000-volt, four-wire, three-phase, power supply. Three 75-to-5 ratio current transformers are connected as shown in the diagram to the two trip coils on the circuit breaker for this motor. I believe this connection scheme is incorrect. It looks like a delta connection, but has one current transformer reversed. I think that a "Z" connection of current transformers should be used, but that is not the case here. Will some reader show me how these current transformers should be connected to insure proper protection of



the motor, and also tell me the proper current setting of the trip-coil plunger, so as to trip at 125 per cent load on the motor? Full-load rating of the motor is 39 amp. The trip coils referred to are solenoids located on the faceplate of the circuit breaker and have plungers operating directly on its trip latch.
Waukegan, Ill. S. D. H.

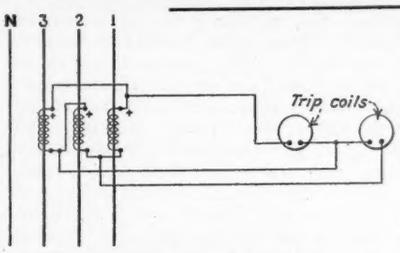
If S. D. H. will remove the left-hand trip coil from the line connecting to X_1 of transformer *A* and X_2 of transformer *C* shown in his diagram and connect it in the line running from X_2 of transformers *A* and *B*, he will have a true "Z" connection. In other words the left-hand trip coil should be connected into the line that S. D. H. shows as the common wire in the diagram accompanying his question.

The "Z" connection is an arrangement such that the resultant of two currents at 120 deg. will equal a third current which is the same as the current in the current transformer secondaries, but has a different angular relation. For the case under consideration the setting of the trip coils should be $39 \times 1.25 \times (5 \div 75) = 3.25$ amp.

C. OTTO VON DANNENBERG.
Designing Engineer,
General Engineering & Management Corp.,
New York, N. Y.

* * * *

The best protection and the one most commonly used requires three transformers star-connected to three relays, but when two relays are used the "Z" connection serves the purpose very satisfactorily. A bad feature of the delta-connected job is that specially wound relays must be used, as the currents in the relays with this connection are 1.73 times as great as that in the



This is a "Z" connection of current transformers and relays as used on a three-phase, four-wire circuit.

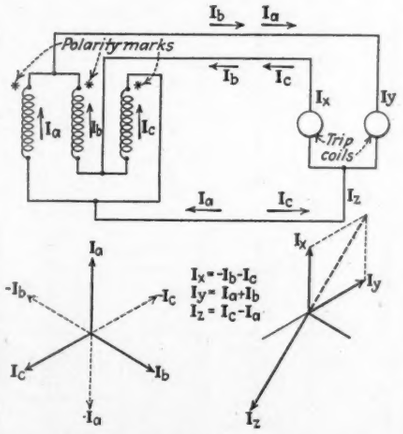
individual transformers, which is not true when the "Z" connection is used.

I would suggest putting in a third relay or using the "Z" connection shown in the accompanying diagram. With 39 amp. as the full-load rating on the motor, 125 per cent rating would be 48.75 amp., and with transformers having a ratio of 15:1 the secondary current would be 3.25 amp. I would suggest passing a current through the trip coil circuit, using an artificial load of 3.25 amp. and adjusting the circuit breaker trips until they operate at this current. I would then consider that I was fully protected, providing the tripping mechanism is kept in good operating condition. E. J. MORRISSEY.
Chief Electrician,
Western United Gas & Electric Co.,
Aurora, Ill.

* * * *

In reply to S. D. H.'s inquiry I wish to say that the scheme of connections accompanying his question is incorrect. With this arrangement, under balanced conditions, one trip coil carries 8.66 amp. when the other is carrying 5 amp. For correct operation each trip coil should carry 5 amp. and a resultant current of 8.66 amp. should complete the circuit through the return wire.

The correct connection for a "Z" arrangement of current transformers is indicated in the accompanying diagram. The direction of instantaneous current flow and related vector diagrams are also shown and should be practically self-explanatory. In all such vector solutions the relative direction of current flow must always be considered. Thus, if the current flow from left to



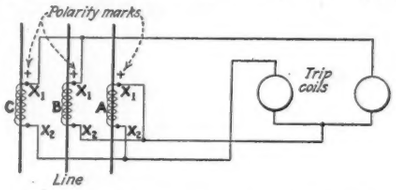
Vectorial relation of current in transformers and trip coils when "Z" connection is used.

right is taken as positive (as it is in this case), then whenever the polarities are reversed the current vector must be thought of as negative. This should explain the values equated for I_x, I_y, and I_z. These three resultant currents as indicated in the vector at the right of the diagram will be found to balance out to zero and, therefore, serve as a check on the connections submitted in the diagram.

The setting of the trip coils for 125 per cent overload thus becomes a simple matter. The current taken at that load is about 50 amp., which gives about 4 amp. through each trip coil if the current transformer ratio is 75:5, and this should be the setting used. Starting conditions must also be taken into consideration as the initial current may exceed the 125 per cent setting of the trip coils, which would then be too low. HENRY B. HANSTEIN.
Brooklyn, N. Y.

* * * *

The connection arrangement of current transformers and trip coils shown by S. D. H. appears to have been intended for a "Z" connection and through some oversight one current transformer was connected reversed.



Interchanging the leads X_1 and X_2 on current transformer *A*, as shown in this diagram will give a "Z" connection.

The correct connections are shown above. As may be seen, the terminals of current transformer *A* are reversed so as to give a true "Z" connection.

The rule for making the "Z" connection is as follows: Connect two positive transformer terminals to the first trip coil terminal. Connect the negative terminals of the first and third transformers to the second trip coil terminal. Connect the remaining positive and negative transformer terminals to the common between the two trip coils. It will be seen that the connections shown in the accompanying diagram meet these conditions.

The "Z" connection is to be preferred to the delta connection, for with the "Z" connection when there is an overload in two lines, the current through the trip coil is the same as in the current transformers, whereas with the delta connection the current through the trip coil with an overload in two lines is equal to the current in a transformer times $\sqrt{3}$. In other words, should the current in the secondary of two current transformers of a delta-connected group reach the normal 5 amp., the corresponding current in the trip coil would be 8.66 amp. Furthermore, the "Z" connection gives better protection in the case of a short-circuit to neutral or ground in a three-phase, four-wire system than does the delta connection, which is another good reason for using it.

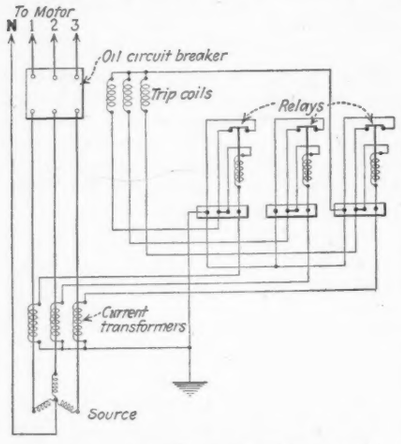
If the "Z" connection is used in the case under consideration, the setting of the trip coil plunger should be 3.25 amp. to trip at 125 per cent load as may be seen from the following: $39 \times 1.25 \times (5 \div 75) = 3.25$ amp. This is based on the assumption that the trip coil plunger is graduated in accordance with the current through its coil.

FREDERICK KRUG.
Supt. of Power Production,
Porto Rico Railway Light & Power Co.,
San Juan, Porto Rico.

* * * *

In reply to the question asked by S. D. H. if his relay connection diagram is correct, he does not show the type of relays used.

If time-limit relays are not used, the protection will be very poor, as with the trip coils set to accommodate the usually large starting current, he will not have running protection unless a separate circuit breaker is used for starting. If a separate starting circuit breaker is used, it will not give the proper protection unless relays are used, as a sudden change in load may cause the circuit breaker to trip. This interruption may be unnecessary, as the overload may have disappeared almost immediately.



A star connection of relays and current transformers may be used on a three-phase, four-wire system.

The accompanying wiring diagram is for General Electric type PQ-3 inverse-time-limit, circuit-opening, overload relays. The inverse-time feature is used to prevent the circuit breaker from tripping during the starting period, or during momentary overloads. As the name of this relay states, the tripping time is inverse to the amount of overload, that is the greater the overload, the less the time required to operate the relay. Standard relays of this type are calibrated for 5, 8, 12 and 15 amp. with a standard 5-amp coil which will carry 5 amp. continuously. This calibration represents the minimum amperes in the relay coil which will lift the plunger and open the relay contacts.

As will be noticed, a star connection of current transformers, relays, and trip coils is used. It can be noticed from the wiring diagram that the opening of the relay contacts removes the shunt across the trip coils. This allows the trip coils to be energized, which in turn trips the circuit breaker.

In setting these relays I would advise obtaining an operating curve from the manufacturer of the relays and setting them accordingly, the trip coils being set for a slightly smaller current than the relays, so that when relays operate, the circuit breaker will trip instantaneously. Much better protection could be had by the use of a separate direct-current trip circuit from a storage battery having a potential of about 100 to 125 volts, but I do not believe your case would warrant the additional expense.

R. H. FINCH.
Chief Electrician,
Blair Limestone Company,
Martinsburg, W. Va.

* * * *

In reply to S. D. H., the following is submitted for his consideration. The scheme shown in his diagram is incorrect, inasmuch as one trip coil is connected to "Z" current and the other to delta current. The "Z" connection should be used throughout, as shown in Fig. 1 of the accompanying diagram.

An explanation of what "Z" current is may help in understanding this connection. The "Z" current flowing through the trip coil is the combination of the two transformer secondary currents of the same polarity. For a balanced load the resultant of these two currents is always equal in value to the current in the third current transformer secondary and is either in phase opposition to it or in phase coincidence. Why this is true can be readily seen from the vector diagram in Fig. 2. Vectors A, B, and C represent currents A, B, and C in the transformer secondaries. These are 120 deg. apart and equal to each other for a balanced load. Assuming the direction of power as indicated, the direction of current in the transformer secondaries will be as indicated by the small arrows. Thus, the combined currents of B and C flow toward the trip coil T_1 and the combined currents of A and B flow away from the trip coil T_2. In other words, the current I_1 through trip coil $T_1 = B + C$ and can be considered to be of positive direction, while the current I_2 through trip coil $T_2 = (-A) + (-B)$ and may be taken as of negative direction.

Referring to Fig. 2, $+B$ and $+C$ added vectorially give resultant $-A$, which is equal to and is in phase opposition to $+A$. Similarly, $-A$ and $-B$ added vectorially will give resultant $+C$.

From the inspection of vector diagram in Fig. 2 it is readily seen that:

$$+B + C = -A$$
$$(-A) + (-B) = +C$$
$$A = B = C$$

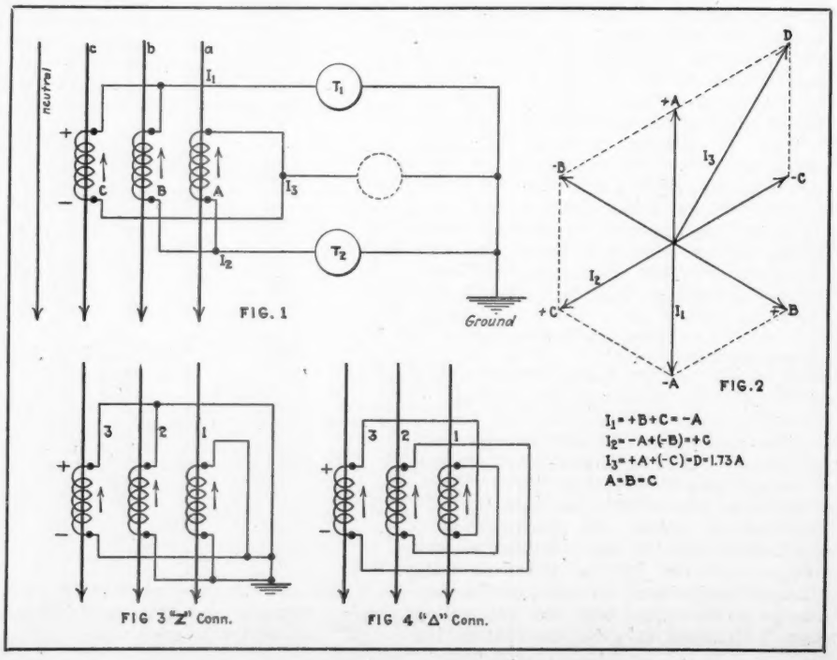
The "Z" connections utilize two positive ends and two negative ends of the three transformers, the remaining positive and negative ends are joined together and grounded. These two currents combined give delta current. This may be seen by referring to Fig. 2 from which we see that $I_3 = (+A) + (-C) = D = 1.73\ A$.

The dotted circle in Fig. 1 gives the location of the trip coil, as shown in the sketch submitted by S. D. H. For obvious reasons this connection is not practical because with a trip coil in this lead, it would receive a current equal to I_3 which is 1.73 times either A, B, or C, with the result that different values of current would be flowing through the trip coils, whereas the "Z" connection gives equal values through both coils.

A simple rule to remember and distinguish the difference between a "Z" and a delta connection is as follows: In the "Z" connection, shown in Fig. 3, the negative end of transformers *1* and *2* are tied together, and the positive end

These diagrams show the difference between the "Z" and the delta connections for current transformers.

Fig. 1 shows the correct "Z" connection. Fig. 2 shows vectorially why the currents in the trip coils are always equal to the secondary current from any one transformer. Fig. 4 shows a delta connection, as contrasted with the "Z" connection in Fig. 3.



of transformers *2* and *3* are tied together. The two remaining ends, the positive of current transformer *1* and the negative of transformer *3* are tied together and grounded. In the delta connection, the positive end of one transformer is tied to the negative of the adjacent transformer throughout, as in Fig. 4.

It should be remembered also that the instantaneous values are considered and due to the use of the somewhat confusing terms "positive" and "negative" it is suggested that "positive" be thought of as the power side and "negative" as the load side of the current transformer.

It will readily be seen from Fig. 1 that both trip coils carry "Z" current, which is 5 amp. at full load in the current transformer primary. This connection affords protection against shorts and overloads. Trip coil T_2 will operate on shorts between *a* and *b*, or overloads on *a* and *b*. Trip coil T_1 will operate on shorts between lines *b* and *c* and overloads on *b* or *c*. Both trip coils will operate on three-phase shorts or three-phase balanced overloads, or on shorts between lines *a* and *c*.

The trip coil setting can be obtained only by actual calibration. At transformer full load (75 amp. in the primary) both coils will carry 5 amp., while the proper tripping value for 125 per cent load is 6.25 amp. The corresponding value for the coil at motor full load (39 amp.) can be found from the proportion $75 \div 39 = 5 \div x$, x being the normal current through the trip coils at the full load current of the motor. Then, 1.25 x is the tripping value.

Solving the equation we find $x = 2.6$ amp. and $1.25 \times 2.6 = 3.25$ amp., which is the desired value.

Trip coils as a rule have a range from 5 to about 10 amp. and can be adjusted anywhere between these values by setting the adjusting nut.

The secondary of current transformer should always be grounded.

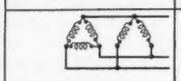
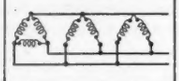
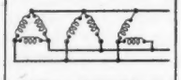
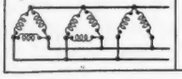
Switchboard Section, B. J. OPARIN.
Westinghouse Electric & Mfg. Co.,
East Pittsburgh, Pa.

* * * *

Paralleling Open-Delta-Connected Transformer Bank with Closed-Delta Bank.—I would like to obtain the experience of some of our readers in regard to parallel operation of an open-delta-connected bank of transformers with one or more closed-delta-connected banks of transformers. Under what conditions is such operation possible? How does the load divide between the several banks of transformers? How is the capacity affected of both the open-delta bank as well as the closed-delta bank? If we have two banks of closed-delta-connected transformers operating in parallel on both the high- and low-tension sides, will these two banks of transformers continue to operate satisfactorily and divide their load in accordance with their capacity, if one transformer is cut out of one bank so as to make an open delta connection? In this particular case, all of the transformers are of the same size, voltage, ratio, reactance, and were made by the same manufacturer.

Wilmington, Del. H. E. H.

In reply to H. E. H., open-delta and closed-delta banks of similar transformers may be satisfactorily operated together in parallel, provided the load is not great enough to overload any single unit in the combination. In the case where five similar transpormers are so connected that there is an open-delta

Method of connecting parallel banks	Three-phase capacity of banks in per cent of combined single phase rating	Number of similar transformers required
	80	5
	72	7
	91	7
	88	8

bank in parallel with a closed-delta bank, the three-phase capacity is 80 per cent of the combined single-phase rating of the five units. Thus, if we consider 100-kva. units, the actual capacity is 80 per cent of the single-phase rating, or $0.8 \times 500 = 400$ kva.

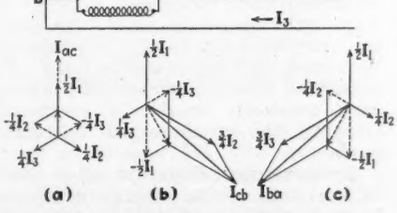
For different combinations of open-delta and delta banks in parallel, the three-phase capacity is different. The diagram and table give the three-phase capacity of several groupings expressed as a percentage of the combined single-phase rating. The data given assume that all units in combination are similar; that is, that they have the same ratio, impedance, and rating. W. C. WOOLEY.

Moloney Electric Co.,
St. Louis, Mo.

* * * *

In reply to the question asked by H. E. H., I wish to say that the capacity of a system consisting of a bank of delta-connected transformers in parallel with open-delta-connected transformers will be increased only 33⅓ per cent. This will be apparent from the following discussion.

If we have two transformers connected in open-delta for three-phase operation they will carry only 58 per cent of the kva. transformed, although we have 66⅔ per cent transformer capacity. This can be shown by letting I be the current per phase; then the line current or output current of the delta bank is $\sqrt{3}\ I$, while that of the open-delta bank is I. Hence, the output of the open-delta bank is $I \div \sqrt{3} = 0.58$ of the output of the delta bank. The transformer capacity is not used,



How the current divides in an open-delta-connected bank of transformers when connected in parallel with a closed-delta bank.

due to the phase relationship of the currents and voltages. In the delta connection, considering a balanced load at unity power factor, the current and voltage of each transformer are in phase; but in the open-delta connection the current and voltage of each transformer are out of phase 30 deg., which results in a power factor of 86.6 per cent for the transformers. In order to have the transformers connected in open delta carry full load their combined rating must be 116 per cent of the delta, considering the delta as 100 per cent.

With the open-delta bank connected in parallel with the delta bank, the increased capacity is not 58 per cent, as might be expected, but 33⅓ per cent. The output of this parallel connection is limited by the rating of the delta connection. The diagram shown below will aid in clarifying the discussion. In this parallel connection, two transformers of the open delta bank are in parallel with two of the delta bank. Hence, the currents in each of the three branches will divide inversely as the respective impedances of these different branches.

Assuming a three-phase balanced load, let I_1, I_2 and I_3 represent the currents between phases *ac*, *cb*, and *ba*, respectively. Considering each phase separately, the currents will divide as follows: Current I_1 breaks up into two paths; $\frac{1}{2}\ I_1$ flows through branch *ac*, while $-\frac{1}{2}\ I_1$ flows through branches *ab* and *bc*. Current I_3 breaks up into two paths; $\frac{3}{4}\ I_2$ flows through branch *cb*, while $-\frac{1}{4}\ I_2$ flows through branches *ca* and *ab*. Current I_3 breaks up into $\frac{3}{4}\ I_3$ which flows through branch *ba*, and $-\frac{1}{4}\ I_3$ which flows through branches *bc* and *ca*. Taking the vectorial sum of these currents in each branch, there results,

$I_{ac} = +\frac{1}{2}\ I_1 - \frac{1}{4}\ I_2 - \frac{1}{4}\ I_3$, as shown at (*a*)

$I_{cb} = -\frac{1}{2}\ I_1 + \frac{3}{4}\ I_2 - \frac{1}{4}\ I_3$ as shown at (*b*)

$I_{ba} = -\frac{1}{2}\ I_1 - \frac{1}{4}\ I_2 + \frac{3}{4}\ I_3$, as shown at (*c*)

It must be remembered that the currents in each branch are displaced 120 deg. and that the indicated signs are vectorial signs; hence, negative vectors are reversed and added to positive vectors.

To illustrate the preceding equations, let us assume a three-phase current of 100 amp. in the line; then substituting in the equations, we have

$I_{ac} = +50 - 25 - 25 = 50 + 25 = 75$

$I_{cb} = -50 - 75 - 25 = 75 + 40 = 115$

$I_{ba} = -50 - 25 + 75 = 75 + 40 = 115$

From this result it is obvious that the winding *ac* which carries 75 amp., limits the output of the system. If the delta bank were used alone, it could carry only 75 amp. However, with an open-delta bank connected in parallel with the delta bank, a 100-amp. load can be carried, which is an increase of 25 amp. or 33⅓ per cent.

FREDERICK NIMMCKE.
New York, N. Y.

* * * *

A bank of open-delta-connected transformers can be operated in parallel with one in closed delta if the characteristics of the transformers composing the banks are the same.

Consider two banks *A* and *B* operating in parallel and both connected in closed delta. If one transformer in bank *B* burns out, this bank may be reconnected in open delta and operated to 85 per cent of its rated capacity in parallel with bank *A*.

Chief Engineer, L. F. Goss.
Kuhlman Electric Company,
Bay City, Mich.

* * * *

Are Transformer Laminations Injured by Burning off Oil and Insulating Compounds? — I will appreciate it if some readers can give me the following information: Does heating transformer laminations to remove the insulating compound and oil injure them? Is it standard shop practice to do this? How much will the iron loss be increased, if any, by this procedure? If the laminations are japanned after burning off the oil and compounds, will this cut down the core loss? Will an oxide form on the iron, during the heating, which will cut down the core loss? How hot may the iron be heated without injuring it?
Santa Ana, Cal. C. C. B.

Replying to the question of C. C. B., it cannot be positively stated that burning off oil and insulating compound from laminations will cause serious heating. If the insulating compound, which is usually some form of japan, has been burned off the safest thing to do would be to obtain new laminations. If this is too expensive or impossible the laminations should again be japanned. It is impossible, except by actual test, to tell whether the core loss is increased.

Whether this method of handling laminations should be followed or not must be left to the judgment and experience of the man in charge. While the oxide that is formed during the heating may help as an insulator, it cannot be depended upon the same as a uniform coating of japan. There may also be a change in the actual space required in stacking, due to the greater thickness of the laminations.

Heating iron to a temperature approaching a red heat causes the formation of a coating of iron oxide on the surface, thus increasing the thickness.

The writer knows of a number of jobs, where the japan and oil were burned off and the laminations restacked without any other treatment. While most of the machines seemed to operate satisfactorily, some trouble occurred which might readily have been attributed to the treatment of the iron. In the case of one large transformer a great deal of trouble in re-stacking was caused by burning off the oil and japan. Possibly too high a temperature was used for this purpose.

C. Otto von Dannenberg.
Designing Engineer,
General Engineering & Management Corp.,
New York, N. Y.

* * * *

Overload Protection for Generators.— (1) We have installed in our power plant, two 2,000-kva. generators and two 4,000-kva. generators, all of which are rated at 2,300 volts, three phase, 60 cycles, 3,600 r.p.m., and are driven by steam turbines. What protection should we have on these generators? Should reverse power relays, or overload relays, or both be used? Are these relays necessary and also what other protection is required on these machines. The four machines are arranged to be paralleled together and quite often all of them are running simultaneously. (2) We have installed one 50-kw., 125-volt, motor-driven generator which operates in parallel with two 100-kw. steam-driven exciters for supplying field excitation for synchronous motors. Should we have circuit-breaker protection on these machines and, if so, should a three-pole circuit breaker be used? I shall appreciate any information that readers can give me regarding these questions.
Detroit, Mich. R. J. B.

For generator protection in the case mentioned by R. J. B., I would suggest first of all a system of grounding through a resistance, the resistance to be of such size as to conform to other points in the station; that is, of high resistance if it is desired to limit a ground current to that of the machine rating or under and of low resistance if it is permissible that the current flowing in event of ground be greater than the generator current.

The protection against internal faults is receiving more attention of late years than was accorded to it in the past and can be accomplished by low-energy over-current relays operating through current transformers placed at each end of the phase winding. With respect to the over-current relay, I would suggest that an over-current directional power relay be used. This will operate to protect against excess current in the wrong direction. An over-current relay may be added to this to protect against plain overload.

In the first case, current must flow in the wrong direction and at a predetermined value and time before the relay functions. In the second case plain overload protection is afforded.

The addition of a power relay offers a means of protecting the smaller units in the event that the larger units are accidentally kicked off or taken off the system.

A circuit breaker of the single-pole type is essential on your exciter sets. The motor driving the set should have the usual protection.

Thermal protection of bearings is not a costly item and offers possibilities in places where adequate supervision is not to be had. They can be installed to ring a signal or shut down the plant and auxiliaries. Also, it is a wise precaution to install graphic meters to record the air temperature on the intake side, with a contact-making element to warn operators in the event of too much heat as a result of the cooling system not functioning.

The use of equipment of this character may save costly repairs and expensive shutdowns.

I hope that these suggestions will be of some value to R. J. B.

Chief Electrician, E. J. Morrissey.
Western United Gas & Electric Co.,
Aurora, Illinois

* * * *

In regard to R. J. B.'s question about protection for a turbo-generator, it is permissible to use either overload or reverse-current relays but I do not see why both should be used. However, the overload relay should be of definite time-limit and not instantaneous. The reason for this is obvious: The momentary overloads would be continually tripping the machine on fluctuating loads.

Temperature relays are often placed in the slots of the alternator winding to prevent the machine from becoming too hot internally; these are arranged to trip the machine at a predetermined temperature.

A protective feature that is much used is the air-washing system for cleaning the ventilating air for the generators. This prolongs the life of the windings by practically keeping dust and dirt from them and also guarantees a cooler operating machine.

Should the machine become suddenly disconnected from the load and the governors unable to control its speed, the overspeed trip on the turbine should automatically shut the machine down, but the overspeed trip should be tested at regular intervals. The best time for this is when shutting down the machine because of light load. Just shift the load onto the other operating machines and then trip the breaker and let the machine speed up, while watching the speed indicator. The overspeed device usually will trip at 10 per cent overspeed.

In the last section of the question I judge that R.J.B. refers to the exciting end of the synchronous motors. In that case no circuit breaker at all is necessary, the exciters being protected by fuses rated at high overload capacity. If a carbon breaker is desired it should be equipped with a reverse-current relay. A single-pole breaker will be sufficient, but I do not see why a three-pole breaker should not be used if this is already in stock. A triple-pole knife switch may be used for the exciters. Also a double-pole switch may be used to handle the negative and positive lines, while the equalizer switch may be of the single-pole type.

Grady H. Emerson.
Birmingham, Ala.

* * * *

Reducing Motor Hum on Large Ventilating Fans.—In the operation of induction motors the lower the speed the greater the motor hum. In some cases however, it is necessary to use low-speed induction motors on ventilating fans and in this case excessive motor hum is objectionable since it is transmitted through the fan and to the duct system. If readers have devised ways and means to reduce the transmission of this hum by suitable mountings for motors when direct connected to the fan by using some fibrous or other material that reduces the transmission of noise, I would like to get details of such mountings. Possibly the noise-reducing device may take some form of coupling between the motor and fan. Please indicate also how magnetic density and variations in slip to get low-speed operation effect motor hum.
Omaha, Neb. H. A. P.

Replying to H. A. P.'s question, induction motors are subject to magnetic noises due to the varying magnetic densities in the iron caused by the alternating currents. I believe this trouble can be helped considerably by using sound-insulating material in the foundation directly under the motor base. Foundations of cork pads 2 or 3 in. thick, felt pads, or sheet lead are some suggestions. Some reputable manufacturers of sound-insulating materials have studied this question of eliminating the magnetic hum caused by a.c. motors, particularly with reference to elevator motors used in large office buildings, hospitals, hotels, and the like, where noise of this nature is objectionable. As a suggestion, I might say that acoustic engineers connected with some of these companies have made careful investigations of this trouble and will doubtless be very glad to furnish valuable information on this subject.

R. F. Emerson.
Industrial Engineering Dept.,
General Electric Co.,
Schenectady, N. Y.

Electrical Service

around the works

For this section short articles describing ideas and practical methods devised to meet particular operating conditions are invited from readers. The items may refer to inspection, overhauling, testing, and emergency or special installations.

Meters Used as Reverse Current Relays Prevent Racing of Rotaries

CONSIDERABLE trouble was experienced in one of our substations from the racing of two rotary converters when the a.c. voltage on the feeders supplying the converters was interrupted. Various mechanisms were tried to provide suitable protection against this condition, but without success, due to the fact that they were not sufficiently sensitive to meet the requirements.

The trouble was remedied finally by the use of two Sangamo Type D-5 d.c. watt-hour meters, one of which is shown in Fig. 2, that were arranged to act as reverse-current relays. The potential coils of the two meters were both connected across the d.c. busbars and the current coils were connected as shunts to the negative leads connected to the d.c. side of the rotary converters, as shown in Fig. 1. The armature connections for both meters were formed by using the respective sections of the two negative leads to which the current coils were connected.

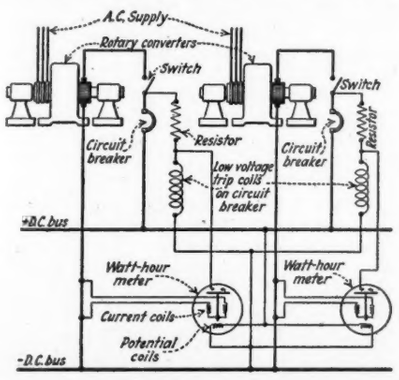


Fig. 1—Connection scheme for using watt-hour meters in the capacity of protective relays.

The meter potential coils are connected to the d.c. busbars and the current coils are connected as shunts to the negative d.c. leads of the converters. When the meter contacts are closed the no-voltage coils are short-circuited, opening the circuit breakers.

The trains were removed from the two meters and leads were brought from the trip coil of the no-voltage release attachment on the circuit-breaker. Each trip-coil was connected to special contacts placed inside the corresponding meter, as shown in Fig. 2. One of the meter contacts is stationary while the other is mounted on the meter disk which is normally grounded in the mercury of the current element. A stop attached to the frame of the meter was also placed in such position as to prevent rotation of the disk in the opposite direction. By adjusting the magnets and the stop for the disk, the inverse-time limit may be varied within quite wide limits.

With the rotaries running at line voltage they are delivering energy to the line and the meters attempt to run forward, but the stop prevents this. If the voltage of one of the rotaries drops below the line voltage, there is a flow of energy back into the machine and the meter swings backward, closing the meter contact and opening the circuit-breaker by short-circuiting the low-voltage coil. This coil is in series with a resistor which prevents any damage from the short-circuit.

This arrangement has provided a most excellent type of d.c., time-limit, reverse-current relay, and has never failed to operate on interruption of the a.c. circuit on either machine. The breakers are always tripped before any variation can be noted in the speed of the converters.

R. C. STEVENS.
Superintendent of Meter Dept., Charleston Consolidated Ry. & Light Co., Charleston, S. C.

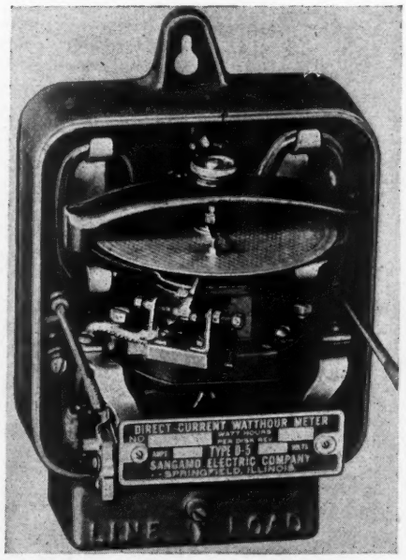


Fig. 2—Sangamo type D-5 watt-hour meter provided with contacts for use as a reverse-current relay.

The disk is kept from turning by the fixed stop at the right. Upon the reversal of current flow the disk will tend to turn in the backward direction, thus closing the contact at the left, which short-circuits the no-voltage coil and trips the circuit breaker.

Methods of Lighting Finish and Assembly Work on a Moving Conveyor

THE following discussion was taken from a paper on "Automobile Body Plant Lighting," presented before the Annual Convention of the Illuminating Engineering Society at Detroit, Mich.

The paper mentioned above was written by James M. Ketch, Illuminating Engineer, National Lamp Works of the General Electric Co., Detroit, Mich., and H. J. Thompson and E. F. Labadie, Electrical Engineers, Fisher Body Corp., Detroit, Mich.

The lighting system used for the finish and assembly of the automobile body deviates from the usual industrial lighting because of the problem of furnishing proper light for work which is on a moving conveyor. However, similar applications will be found in other industries, which may be handled likewise.

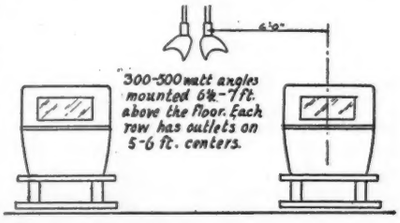


Fig. 1—Lighting arrangement for the conveyor line when work is being done on the exterior of the automobile bodies.

The problems confronted when lighting the bodies on moving conveyors are essentially the same for the several important operations found there. The surfaces to be lighted are vertical and probably of a dark color, and the bodies are traveling at a slow but constant speed. In some plants the conveyor lines are close enough so that one side of two lines, or the bodies on both sides of the work aisle, can be lighted with one line of luminaires in the center. In many plants, however, the lines are too far apart to be effectively lighted this way, and each side of a conveyor line must be considered as a separate problem. This requires duplicate lines of reflectors in each aisle.

One company flows enamel on the bodies while they are suspended by chains from a traveling conveyor and the bottom of the body is at least 3 ft. above the floor. This body height makes it fairly easy to get proper illumination on the entire side with lumi-

naires mounted at heights of 7 to 8 ft. In other plants the bodies are mounted on trucks on a floor conveyor with the most important lower surface from 20 to 24 in. above the floor. As floor space is at a premium for automobile bodies and workmen, it seems impractical to locate any sort of lighting equipment on the floor; hence the use of low-mounted reflectors 6½ to 7½ ft. above the floor is more common than the use of those mounted at heights usual in factories.

The intensities required are high. Levels of 20 to 50 ft.-candles are standard for black, blue and dark gray jobs, while intensities of 15 to 35 ft.-candles are sufficient for work on the lighter blues, grays and gray-green color now so popular. In general, body conveyor line lighting requires special equipment and there is a wide field for the development of reflectors that will do the job with utilization efficiencies obtainable in other and more common industrial lighting systems. With the commercial equipment now available, angle reflectors seem to give the best results.

The standard of one large body company is to use 300-watt elliptical angle reflectors mounted 6½ to 7 ft. above the floor, and spaced 2½ to 3 ft. apart alternately facing opposite sides of the work aisle, thus giving an effective spacing of 5 to 6 ft. on any one side as shown in Fig. 1. Where color is very important, 300-watt, bowl-frosted daylight Mazda lamps are used, and 300-watt, clear lamps where the intensity is of more importance than the color. The elliptical angle at this height directs a high percentage of vertical illumination to the side panels and yet has a deep enough shielding angle to eliminate objectionable glare to anyone facing the row of units from the opposite side of the conveyor line.

Many schemes and devices have been tried for lighting the inside of closed bodies in the trimming and upholstering departments. While it is possible to light the body from stationary lighting systems, such systems generally prove impractical because of the need of plenty of man-space in the aisles between the conveyor lines. Where the bodies being trimmed are stationary, it is undoubtedly the most satisfactory plan to use portable extension cord or portable floor stands. In the larger plants, however, the trimming is done while the bodies move along on the conveyor line and extension cords attached to stationary outlets are generally in a hopeless tangle. The plan of lighting the dome and side-lights of the automobile by means of a third rail and sliding collector system attached to a low-voltage system has been tried. However, the voltage drop, due to poor sliding contacts and the resistance of the long steel tracks, has almost discouraged this practice.

A better plan is to install an overhead, hard-drawn, copper-wire trolley with simple sliding collectors attached to the ends of extension cords, as in Fig. 2. These collectors can be simply and cheaply made and their operation has been satisfactory. As the car moves along on the conveyor, the extension cord in the car slides the collector along the trolley, eliminating the

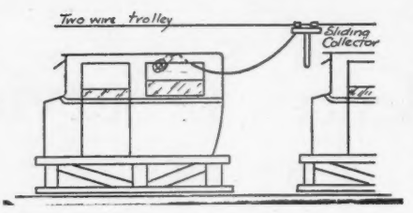


Fig. 2—Trolley and collector system for lighting the interior of the bodies when they are on the conveyor line.

usual tangle of cords where stationary outlets are in use.

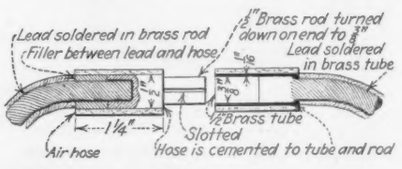
In using this device the trimmers wrap a piece of tape around the cord near the socket and tack it to one end of the wood braces in the body top where it takes care of itself until he has finished with that body. Gathering up cords and tools, the trimmer merely lifts the collector off the trolley and moves back the line to a new body. At first, the trimmers did not entirely understand the trolley system and would short-circuit the line by hanging metal gutter strips over the convenient bare trolley wires. Blown fuses or circuit-breakers are now prevented by putting two 1,500-watt lamps in parallel, and in series with one side of the line. These lamps have large enough current capacity to carry the total current of the extension cords without lighting up; yet they serve as a safety device, and indicator of trouble, by lighting if the trolley is accidentally short-circuited.

How to Make Portable Power Connector for Hard Service

AFTER trying several makes of power connectors and finding none that would stand the weather and abuse around a strip mine, I designed the one shown in the accompanying illustration.

As will be seen, this connector consists of a male and female portion, each of which is protected by a piece of ½-in. air hose. The male end is made from a piece of ½-in. brass rod which is drilled out at one end to receive the conductor. The other end of the rod is turned down to a diameter of ⅜ in. and slotted as shown. After slotting this part is is advisable to spread it slightly so that it will make better contact and be held more firmly in place.

The female end of the connector is made of a piece of ½-in. brass tube with an inside diameter of ⅜ in. The lead is soldered in the brass tube, leaving a sufficient length of the tube open to receive the male portion. The pieces of air hose, which should be about 1¼ in. long, should be cemented in place over the tube and the rod. One important advantage of the hose is that it does not warp when it becomes wet, and will stand more abuse than a fiber handle or sleeve.


Lead soldered in brass rod
Filler between lead and hose
1" Brass rod turned down on end to ⅜"
Lead soldered in brass tube
1¼"
½ Brass tube
Slotted
Air hose
Hose is cemented to tube and rod

Here is a portable power connector that is easy to make and has proved very satisfactory in service under severe conditions.

This power connector has proved entirely satisfactory in service and will be found very useful wherever portable cords are used under severe conditions.

R. C. VORDERSTRASSE.
Chief Electrician,
United Electric Coal Co.,
Lewistown, Ill.

Heating Caused by Carrying Each Phase of 3-Phase Circuit in Separate Conduit

IN THE February, 1926, issue, S. H. Samuels described, on page 93, the method used to correct the high temperature and unbalanced conditions caused when separate phases of a three-phase circuit were carried in individual conduits. The heating referred to was probably caused by the use of conduit made of magnetic material, constituting in effect a transformer with a one-turn secondary. The remedy that was used is essentially the same method employed for carrying connections from an electric furnace transformer to the electrodes. The conductors are so interconnected that each carries a smaller current adjacent to a line of different polarity, and the lines are grouped or interleaved, particularly when copper bars are used as conductors.

A case of trouble occurred some years ago which was solved in a different way. An iron pipe conduit system somewhat over ¼ mile in length was installed with the intention of using a three-conductor cable later on. Owing to a change to higher voltage on the system and an increase in the load to be carried, it was not possible to use a three-conductor cable that was small enough for the duct; so a single conductor had to be used. It was out of the question to draw in a single cable in each duct, due to the danger from excessive heating as well as the added inductive drop.

The matter was solved by drawing two cables of the same size and insulation into each duct. One cable ran straight through from one station to another, but the other or auxiliary cable was connected to two other auxiliary cables at the end of the iron conduit run. This gave the same result as inserting three current transformers, in three separate lines, with the secondaries short-circuited, the main cable being the primary. Since the current flowing in the short-circuited secondary sets up a magnetic field which very nearly neutralizes the magnetic field set up by the primary, the resultant magnetic field left to magnetize the conduit is small. Therefore, there is no heating, and the added inductive drop due to the section of iron pipe is negligible.

C. OTTO VON DANNENBERG.
Designing Engineer,
Sanderson & Porter,
Springdale, Pa.

Facts to Remember About Care of Renewable Fuses

A FUSE is the maintenance man's best friend, when it is properly applied and cared for; otherwise it can be the source of no end of annoyance, as well as the cause of considerable delay to important machines which it is supposed to protect. Although renewable fuses are extremely simple, there are several precautions that should be observed in using them. It is surprising, but true, that some maintenance men will install a fuse improperly and expect it to give good service. It is sometimes still more surprising to visit some power plant and note the number of fuse cases, terminals and so on laying around that have been burned up or so badly damaged that they are of no further use. I cannot say just what the life of a good renewable fuse should be, as I have never had to take a fuse case out of service, in spite of the fact that I have refilled them hundreds of times and used them in some cases at 100 per cent above their rated capacity. With this in mind, the following procedure may be of help to maintenance men who have been having trouble with fuses.

First, I always keep a duplicate set of fuses ready for use in a small rack in the power house. Under each set of fuses is marked the equipment on which these fuses are used and the rating that is best suited for its protection. When a set of fuses fails anywhere in the plant, I can replace it with the extra set in a very short time indeed.

As soon as possible, I take the blown fuses apart, polish the terminals and washers, and also the fuse links, if they are old and discolored, with a small piece of No. 00 sandpaper, and assemble the fuse carefully. I take particular care to make a good, tight fit between the link and the terminals. Right here is where a great many maintenance men make a mistake: they do not tighten the link in the terminals as well as they should, which results in a temperature rise at the terminals when the fuse is put under load. The heat is in turn passed along to the link and the result is a premature failure.

Another very important point that deserves more attention than it usually receives, is the condition of the fuse clips. I make it a point to go over all fuse clips at least once a month, remove the fuses, and carefully wipe the inside of the clips with a folded piece of No. 00 sandpaper where they make contact with the fuse terminals. After doing this I try the fuse in the clip, noting carefully whether both clips make a good, firm contact with the fuse terminals. If not, it takes only a few light taps near the base of the clip to make a tight fit. A little experience will soon enable one to do this.

Another important point to watch is whether the fuse clip is making contact with the fuse terminal on only one corner on either side of the clip. By inserting and withdrawing the fuse a time or two, one can see by looking at the fuse terminals just what parts of the clips are making contact with the fuse terminals. In a surprising number of cases, fuses make contact on just a very small part of the clip. If this condition is not corrected, the fuse cannot possibly carry its rated load, due to the fact that the area of contact is so small that it will heat up when the fuse is put into service. The result is premature failure, causing unnecessary delay and expense. Besides this, the fuse terminals and clips will probably be burned, in some cases so badly that they can not be used again. In any case, heating anneals the fuse clips and takes all of the life out of them. With the larger sizes of fuses, this heating, in addition to burning the fuse terminals and annealing the fuse clips, may also cause the fuse case to crack and split open.

All of the above instructions can be carried out in much less time than it takes to explain them. If they are complied with, it will be found that fuses will give not only months but years of faithful and reliable service, eliminating the annoyance and delay to production occasioned by premature failures due to abuse and improper care.

Chief Electrician, F. D. HEWLETT.
Ingham-Burnett Lumber Co.,
Allison, Ala.

Supposed Electrical Trouble with Hoist Motor Due to Mechanical Cause

WHILE relieving the electrician in a local plant, I was called to start a 3-ton Euclid hoist which was driven by two small, three-phase, 220-volt induction motors. One of these motors operated the hoist, being direct-connected to the drum through gears, and the other operated the bridge motion through a belt. The bridge motion motor ran nicely, which indicated a good contact on the main trolley shoes or wheels, but the hoist motor would not start. So the usual tests for blown fuses, bad contacts at trolley shoes, and an open circuit were made. All taped joints were inspected and the contacts at the reversing controller were gone over. In fact, every ordinary test was made to insure that the motor was receiving current, and all tests showed that the motor was undoubtedly getting current. The bearings were also examined, and were found to be almost perfect. The motor was in perfect shape, literally speaking, was getting the required current, but still would not run.

I took the front end bell off the motor and put an 18-in. pipe wrench on the shaft and pulled both ways, but could not move the rotor. The condition of the rear bearing showed that it was not frozen, because it was not even warm, had plenty of oil, and the motor had been running a few minutes before. A fine mill file was sent for and used to remove the burrs from the shaft caused by the pipe wrench.

We next removed the cover from the gear box. After carefully looking over the gears, it was found that a spring had become loose from its support on the load brake and had wedged between the main gear and the gear housing. This spring is used on the load brake and is about 3 in. long by ⅛ in. in diameter. It had been pulled up almost its full length between the drum gear and the housing. When the spring was removed and replaced by a new one, and the front end bell again put on, the motor ran normally.

Because of a rather unusual ruling in this plant, to the effect that the electrician was not allowed to make mechanical repairs, I was merely an interested onlooker while the above repair work was being done. However, this incident impressed on me the fact that the mechanical end of a motor drive is oftentimes a source of trouble and should be carefully inspected when ordinary tests have failed to reveal the cause of supposedly electrical trouble.

Birmingham, Ala. G. H. EMERSON.

Method of Grounding Machines to Prevent Static Discharges

DISCHARGES of static or frictional electricity from machines used in manufacturing processes are always a source of annoyance and danger to the persons operating the equipment. There are cases on record where employees have been seriously injured, either directly or indirectly, by discharges of this kind.

Static electricity is generally developed on belt-driven machines that are set up on wooden flooring, or on a flooring having fair electrical insulating properties, and where the main drive shaft bearing brackets are mounted against a wooden ceiling. In many cases belts are grounded by means of metal combs placed close to the belt surface to remove the static charge.

The methods of preventing trouble from static electricity are extremely simple, and consist in grounding the frames of the machines to a suitable conductor going to earth.

There are, however, a few points to keep in mind when installing ground connections. As a rule, a ground wire is run to the nearest water or gas pipe, regardless of the conditions or the troubles that are quite likely to develop later.

Consequently a few suggestions may be helpful. In the first place, avoid grounding wires on fire sprinkler heads, steam pipes, gas pipes, meters, valves, and conduits. There is always danger of a pipe, especially a steam pipe, being insulated from the earth, or leaking gas being ignited, with the possibility of frequent repairs making the ground ineffective for certain periods. Machine ground wires should be run so that they will not be mishandled and broken, to become a hazard to employees.

A simple and effective method of grounding any number of machines is to connect them to a common copper wire, say No. 6 B&S gage, which is carried along the floor and outside the building in conduit. The conduit serves merely as a physical protection for the wire which should be soldered or welded to a copper plate imbedded in several layers of charcoal placed at a sufficient depth to be in permanently damp earth. This method is recommended by the Department of Safety and Labor in several states.

Jersey City, N. J. E. A. BAERER.

Mechanical maintenance of Power Drives

This department will furnish mechanical details of installation, operation and maintenance of equipment in the path of power service from the first mechanical driving element through the auxiliary transmitting equipment to all driven machines.

How an Uneven Belt Was Made to Run True

THE defective portion of the driving belt of a high-speed, three-bearing generator was recently removed and replaced by a new piece. When the machine was started following the repair, the belt persisted in running off to one side, which brought one edge in contact with the outside bearing pedestal of the generator. This was probably due to stretching of one side of the old belt, or to a splice which was not square with the edge. It was easily seen that if this were permitted to continue, the edge of the belt would soon become stretched and worn and flare out. This would soon destroy the belt.

The difficulty was overcome by transferring the crown of the driven pulley from the middle of the pulley face to a point nearer the center bearing. A ring of ⅛-in. holes was drilled around the pulley face about 1½ in. to one side of the old crown at the place it was desired to have the new crown and a strip of raw-hide belt lacing riveted to the pulley base. When the machine was started, the belt ran true on account of the action of the new crown. The pulley was enough wider than the belt so that it did not run off at the other side when shifted over by the new crown.

Another way to build up a crown, or to shift a crown to one side of the center of a pulley, is to use cloth and some of the various pulley cements on the market. When this method is used it is not necessary to drill holes in the pulley face, nor does it leave a row of projecting rivet heads around the new crown.

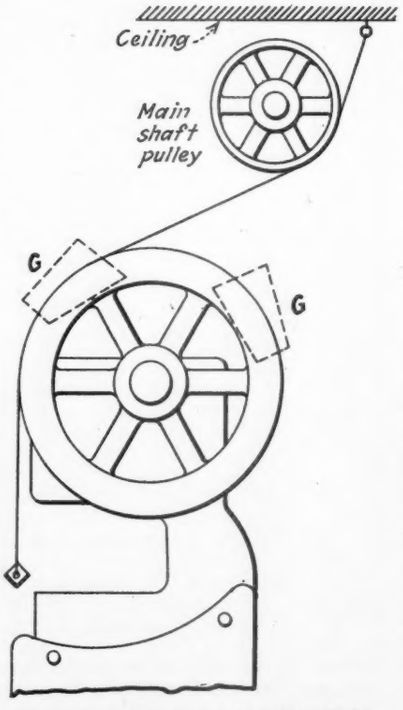
Safe Method of Lining Transmission Guards While Operating

EVERY millwright has had to do jobs after working hours because of the risk or impossibility of working around moving transmission equipment. Even the measurement of belt lengths by use of a tape over the pulleys is fraught with danger and difficulties. The accompanying drawing shows a method of doing, without risk and in a most simple manner, a job in which moving pulleys figure.

Two guards were to be applied to the belt and flywheel, which also served as the pulley, of some punch presses and attached at the points *G* and *G*. The guards themselves were of the box type which provides a bell-mouthed opening for the belt and also has sides which completely enclose the pulley and belt on the exposed sides. It is obvious that the only way to set these guards properly is to have the belt or its equivalent in position.

To attach the guard it was necessary, for safety, to have the press idle because of the danger of working around a moving flywheel. With the belt thrown off the flywheel there was no means of lining up the guard. For this reason it had been considered necessary to do the work at night. In order to avoid overtime work on this occasion, the millwright in charge threw off the belt and substituted a line, as shown in the accompanying sketch. The first step was to attach a small eye to the ceiling above the pulley on the lineshaft. A cord was fastened to this eye and carried over the moving pulley on the lineshaft and on down over the flywheel on the press. A nut on the end of the cord served as a weight to hold it in position. This cord provided him with a true belt line from which he could accurately place his guards, which were secured by angles to the frame of the machine.

Following this same method the whole battery of machines was fitted during working hours. It was necessary to have only one machine idle at a time and it was possible in every case to find periods when the machines were idle for other reasons. In addition, the whole job was done better than would have been the case at night, and by a simple, safe method that is applicable to many other jobs around moving pulleys.



By using this string instead of the belt it was possible to line up the guards during working hours and while the lineshaft was operating.

It may not be out of place to mention that this incident serves as another illustration of the fact that the most obvious method of handling a job is not always the best method. For this reason a little time spent in planning the work and deciding just how it may be done with the greatest ease and safety, all things considered, will usually be well invested.

This is particularly true in the case of operations or work that ordinarily would mean stopping equipment for a time, or that involve an injury hazard to the workmen, as in this instance. Usually one has but to calculate the value of the output of a machine or group of machines, with the wages of the operators, for even a comparatively short period of time to be convinced of the advisability of avoiding shutdowns as much as possible, when work is to be done on power drive equipment. However, pursuit of this ideal should not be carried to the point where the workmen are exposed to any unusual hazards.

DONALD A. HAMPSON.
Plant Superintendent,
Morgans & Wilcox Mfg. Co.,
Middletown, N. Y.

Comment on "Specifications for Oil and Grease Lubricants"

IN THE discussion of the sludge test in the article entitled, "Specifications for Oil and Grease Lubricants," which appeared in the March, 1926, issue of INDUSTRIAL ENGINEER the following statement appeared: "The sludge test, which determines the tendency to form a sludge, has comparatively little bearing on lubrication, but is of interest to the manufacturer and important in determining the insulating life and value of transformer oils."

Attention has been called by readers to the importance of the sludge test on an oil used in the lubrication system on turbines and other equipment where the oil is circulated continuously. This article was intended to cover only lubrication problems incidental to power transmission equipment and plant machinery. A discussion of engine and turbine lubrication is extensive enough to demand individual treatment.—EDITORS.

Determining Size of Pulley for Fabric-Base Belts

WHERE fabric-base belting is made up of several plies of stitched or cemented canvas, pulleys of small diameter should not be used because of the danger of pulling the plies loose when making the short bend.

The proper size of pulley to use with such belting of various weights and plies may be determined by means of the accompanying chart which takes into consideration working stresses ranging from 210 to 280 lb. per sq.in. The three most common weights of duck used in belts, 28 oz., 32 oz., and 36 oz., have corresponding working stresses of 220, 237 and 252 lb. respectively. These stresses are given in column *A*. Column *B* gives the minimum pulley diameter in inches and column *C* the number of plies. With this chart any of these three factors may be found if the other two are known.

The method of using the chart is best shown by an example. Thus, if a seven-ply belt is made of 32-oz. duck, what minimum pulley diameter may be used? To find this run a straight line through the point in column *A* corresponding to 32-oz. duck and figure 7 (number of plies), in column *C*; the intersection of this line with column *B* indicates that the minimum pulley diameter that should be used with such a belt is 18 in.

In other words, simply run a straight line through the working stress, column *A*, and the number of plies in column *C*, and the intersection of this line with column *B* will give the minimum pulley diameter. Extremely small pulleys must be avoided, if it is at all possible to do so. Thus, column *B* shows that no pulley smaller than 5 in. in diameter should ever be used with a standard fabric belt.

Data for Proportioning Fabric-Base Belts

Belt Width, Inches	Number of Plies, Minimum	Number of Plies, Maximum
2	2	3
3	3	4
4	3	5
5	4	5
6	4	5
8	4	6
10	4	6
12	4	6
14	5	6
16	5	6
18	5	6
20	6	7
22	6	7
24	6	7
26	7	8
30	7	8
36	8	10
42	8	10
48	8	10
54	10	12

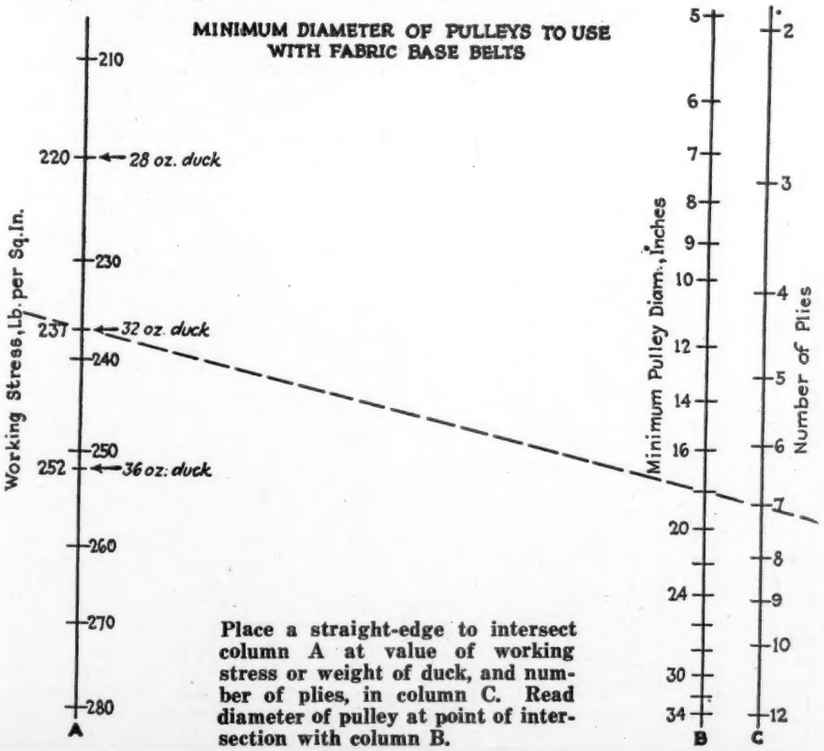
This chart is based upon the following rule: Extract the cube root of the working stress in pounds per square inch, multiply by the number of plies and divide by 2.4. The result is the minimum diameter of the pulley in inches.

This chart may also be used for determining the maximum number of plies when the working stress and the pulley diameter are known, by simply runing a straight line through the two known factors.

The accompanying table will assist in the selection of a well-balanced belt that will be neither too thick nor too thin. Thus, for instance, if the belt width is 10 in. it is generally considered best not to use less than four or more than six plies. This table used in conjunction with the chart will be found to be very useful when laying out fabric-base belt drives.

W. F. SCHAPHORST.

Mechanical Engineer,
Newark, N. J.

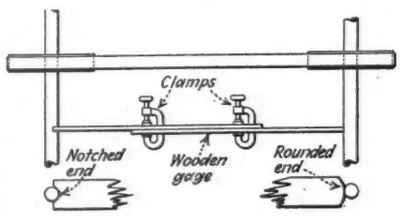


Place a straight-edge to intersect column A at value of working stress or weight of duck, and number of plies, in column C. Read diameter of pulley at point of intersection with column B.

Easily Constructed Gage for Aligning Shafts

ON PAGE 193 of the April, 1926, issue of INDUSTRIAL ENGINEER appears an interesting item by Maurice C. Cockshott entitled "An Easy Method of Aligning Parallel Shafts." I have a method that I believe is better for certain conditions, particularly where the end of the shafting is difficult of access, and for quickly checking the alignment. This method does not require any careful measuring or marking by use of a carpenter's try-square.

The equipment required can be quickly put together in any plant. It consists of two pieces of light, slender but stiff, wooden strips and two light clamps, as shown in the accompanying sketch. With a gage like this, clamped together at a length equal to the distance between the shafts at one point, it is a simple matter to check the shafts at other points and learn whether or not they are parallel. If the shafts need aligning the gage will touch only at the points of minimum distance; but if the shafts are parallel, the gage will "just touch" at both ends at every place of measurement. If one end of the gage is V-notched to fit over the shaft so that it will not slip off and the opposite end rounded, the gage can be handled more easily.



The construction and method of using a light wooden gage for checking alignment of parallel shafts is shown here.

Wooden gages are far superior to a cord because wood does not stretch or shorten according to the tension. Also, a light wooden stick can be handled with ease and certainty. It is even better than a steel tape, in that it is easier to get the exact distances between the shafts.

In almost any plant where much shafting is used, it is worth while to make a gage of this kind to keep on hand for use as a permanent tool. When fitted together with a tongue-and-groove joint the two pieces can be adjusted more quickly than without such a joint. However, two plain sticks will serve the purpose very well in an emergency.

Newark, N. J. W. F. S.

In the Repair Shop

This section is devoted to repair work on electrical and mechanical equipment. Special attention is given to shop or bench tools and short cuts or improved methods of handling work of this character. Contributions are always welcome.

How to Meet Emergency Demands for Brushes in the Repair Shop

CARBON brush stock carried by various repair shops will be found to vary greatly. The larger shops often carry a large stock of special brushes ready to place in the machine, but the stock of special brushes kept in the small shop must necessarily be limited. However, it is important that the latter be able to meet most brush needs at short notice. Any repair shop will be helped greatly in meeting emergency demands by keeping in stock a few plates of carbon from which brushes of various sizes may be cut. These plates can be obtained 4 in. by 8 in. in size and of almost any thickness desired. Carbon stock can also be secured in rods of various diameters.

Round brushes may, if necessary, be cut from plate or flat stock and if a little care is used they will be satisfactory in both appearance and service. In making a small round brush from flat stock, cut a square brush of the required length and a little larger than the diameter of the required brush. By cutting off the corners, an 8-sided or 16-sided piece may be made, depending upon the size of the brush required. If a piece of sandpaper is folded over the brush and the latter turned, the surface will soon become round and smooth.

J. P. COLLOPY.

Fort Collins, Colo.

Method of Reconnecting 2,200-Volt Synchronous Motor for 440 Volts

SOME time ago in the reconstruction of an industrial plant all induction motors, which previously had been connected for 2,200 volts, had to be replaced by 440-volt motors or reconnected for this new voltage, where possible. Among those to be reconnected was a synchronous motor.

This particular motor was originally designed for 165 hp., 2,200 volts, three phase, 41 amp., 900 r.p.m., 96 slots and 48 coils, or 16 coils per phase. Fig. 1 indicates how the coils were originally connected series-star.

In reconnecting for 440 volts it was decided to use a composite delta-star connection, which is shown in the schematic diagram of Fig. 4, having three paths in the delta portion and five paths in the star portion. Using a 440-volt power supply the line current required is 41 (amp.) × 2,200 (volts) ÷ 440 (volts) = 205 amp. Since there are five paths in parallel the current in the star portion of the connection (that is, from *A* to *E*, *B* to *F*, or *C* to *H*) will be 41 × 5 = 205 amp. Now the phase current in the delta portion of the connection (that is *E* to *F*, *F* to *H*, or *H* to *E*) must be the line current divided by $\sqrt{3}$, or 205 ÷ 1.73 = 118.4 amp. This portion of the winding, however, is capable of carrying 3 (paths) × 41 (amp.) = 123 amp., from which it is seen that the current flowing in the winding is practically the same as it was before reconnecting the motor.

The original series-star connection was changed to a delta-star combination.

The original connections of the motor are shown in Fig. 1. The vector diagram in Fig. 2 shows the phase relations and voltage across any two phases when reconnected. The schematic diagram of a four-parallel star connection in Fig. 3 indicates the preliminary steps in the new connection scheme. Fig. 4 shows the composite delta-star connection with three paths in delta and five paths in star, which was required for the new voltage.

To find what the line voltage should be, let us refer to the vector diagram in Fig. 2. In the original connection of Fig. 1 the line voltage is 2,200 volts; so the voltage across each phase is 2,200 ÷ 1.73 = 1,271 volts and the voltage per coil is 1,271 ÷ 16 = 79.4. In Fig. 4, we have two coils in series between *B* and *F*, (the star portion of the winding), the voltage is 2 × 79.4 = 158.8, and since the delta portion between *E* and *F* is in phase with the star portion between *B* and *F* the voltage from *E* to *B* is 2 × 158.8 = 317.6 volts. However, *AE* which also represents 158.8 volts is 120 deg. out of phase with *EB;* so these voltages must be added vectorially to find the total voltage across *AB*. If the diagram in Fig. 2 is carefully drawn to scale, it will be found by measuring that the voltage from *A* to *B*, *B* to *C*, or *C* to *A*, is nearly 415 volts, which is close enough to 440 volts for operation.

An easy way to make this connection is to draw the schematic diagram for the four-parallel star connection, as shown in Fig. 3, with equalizer connections at *a*, *b*, *c*. Now place the coils *g*, *e*, *f*, of Fig. 3 at *g*, *e*, *f*, in

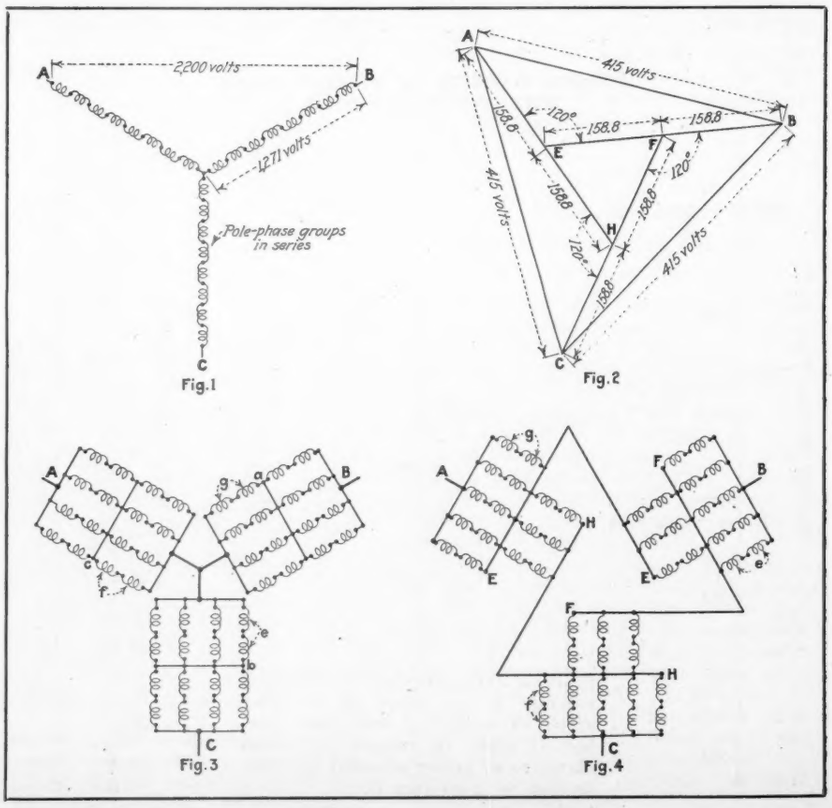


Fig. 4 thus locating them between the line leads and equalizer connections and making five pole-phase groups in parallel.

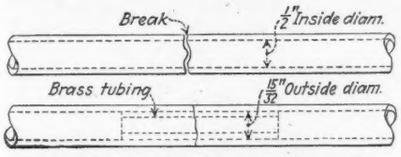
The star connection in Fig. 3 is now broken and the star leads connected to the equalizer lead of the adjacent phase, as shown at *E*, *F* and *H* of Fig. 4. This results in connecting the pole-phase groups between *H* and *E*, *E* and *F*, and *F* and *H*, to form the delta portion of the winding.

W. L. STEVENS.

New Westminster, B. C., Can.

Method of Reinforcing Light Metal Tubing Before Welding

AMONG the miscellaneous repair jobs which the industrial maintenance department is frequently called upon to handle, is the welding of broken steel and brass tubing. This is a troublesome job because the walls of the tubing are very light and melt quickly under the heat of the welding equipment. The result is an ever-enlarging hole. A method of over-



Using an inside sleeve enables the operator to weld light tubing without burning the metal.

coming this, as recommended by The Linde Air Products Co., New York City, is shown in the accompanying sketch.

In this instance, when welding a piece of tubing ½ in. inside diameter, a short length of 15/32-in. tubing, outside diameter is slipped inside of it. This makes an inside sleeve which provides a backing for the weld. If acetylene welding is used, it is recommended that a ⅛-in. bronze rod and a small flame with little heat should be employed on steel tubing, as the metal is thin. If the tubing is of brass, a ⅛-in. brass welding rod is recommended.

Rewinding Job Simplified by Changing Coils

QUITE often in rewinding armatures, the construction of the coils is such that a large number of reels of wire are required. Many individual reels of wire require considerable floor space and, if the wire is small, much difficulty is encountered in the subsequent handling of the coils throughout the various operations. The following discussion will describe how a good-sized order was obtained by carefully checking the coil construction and using a method of improving it.

The armatures quoted on for complete rewinds were for 50-hp., 500-volt, series, d.c. motors, and the minimum number specified was 12 per year. We were allowed to inspect the armatures at the customer's plant and upon asking for a sample armature coil, were given one that had recently come from the manufacturer. Inspection showed that these armatures had 31 slots and 155 bars and that each single coil was wound with two turns of three No. 14 d.c.c. wires in parallel. Since there were five single coils per winding unit, each coil would require 15 reels of wire to wind it. The coils were of the diamond, mush or pulled type with leads on the bottom and three wires in one sleeve or six wires in each commutator neck. In each slot there were five single coils containing six wires each, or a total of 30 wires placed five wide and six deep.

The insulation on this sample coil consisted of one and one-half turns of 0.01-in. treated cloth wrapper in the slot cell on the top and bottom sections of the coil. The outside cotton tape was 0.007 in. by ¾ in., which was wound half overlapped over the entire coil. Before pulling the coil into shape, 0.004-in. fiber strips were placed between each single-coil layer of six wires; then the coil was pressed and pulled. A layer of 0.0045-in. by ¾-in. cotton tape was applied sparingly on the ends of the slot sections and the coils were brushed with shellac, to hold the wires in place. The sleeving was tied at the end of the slot section with twine.

This customer had been rewinding his own armatures but the winding foreman found that they always had trouble in doing it. As the crossed wires in the coil ends were large, the necessary pounding to get them in place often shorted the turns. These motors were worked hard, quite often carrying considerable overload for a number of hours; consequently, a rewind did not last very long.

The first step in figuring for the job, was to find a way to reduce the number of wires in hand and to stiffen the coil. This led to the consideration of a ribbon wire which would have the same bare copper thickness as before, in order that the same size of slot could be used in the commutator necks. Accordingly, the copper would have to be 0.064 in. thick and not wider than $3 \times 0.064 = 0.192$ in., which would require at least 10 per cent more copper.

On checking a local supply house, it was found that they had only a stock size of 0.064-in. by 0.182-in. bare wire having 14,100 circ.mils area on which we were able to obtain quick delivery. Now, the three 0.064-in. wires in parallel had an area of $3 \times 4{,}100$ or 12,300 circ.mils; then the 0.064-in. by 0.182-in. wire had $(14{,}100 - 12{,}300) \div 14{,}100 =$ 0.127 or 12.7 per cent more copper. Using the 0.064-in. by 0.182-in. d.c.c. ribbon wire meant that only five reels of wire would be required in place of the 15 which were used formerly, and the coil ends could be kept solid and square. By spacing the finishing tape in the slot section, we were able to use a 0.015-in. fishpaper insulation between turns in the slots and also around the rear of the loops, in addition to a 1½-turn mica and fishpaper wrapper.

The customer approved the new winding, as was expected, and the number of rewinds per year were decreased as a result of the different coil construction.

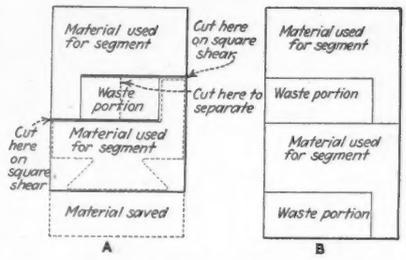
A. C. ROE.

Wilkinsburg, Pa.

Method of Cutting Mica Segments to Save Time and Waste of Material

WHEN making mica segments for repairing commutators the usual practice is to take a rectangular piece of mica the approximate length and width of the segment, and laboriously shape it with a hacksaw and file. It is, of course, necessary to saw and file the dovetails to shape, but a saving in mica and labor on radial-type commutators is made possible by cutting two segments at one time with the square shear, usually found in a repair shop. Diagram *A* in the accompanying illustration shows the new method of cutting out segments, while *B* indicates how it is usually done.

After the mica has been cut into rectangular shape of sufficient size for two segments, the gage on the square shear is set the right distance from the



The segments are laid out and cut as shown in *A*

B indicates the waste of material caused by cutting the segments in the usual manner.

blade to form the body portion of the segment, and a cut is made approximately the length of the wearing surface. It is best to block the blade of the shear so that it will not cut off the riser portion of the segment. This can be done with a wooden block, or if there is much cutting to be done it is better to make an adjustable stop with a screw fitted into the bottom of the blade guide. It will be necessary to experiment a little with some scrap pieces of mica to determine the amount of blocking required. One will find it better to have the slit too short than too long as the radial portion must not be cut into or it will break off. The mica strip is first cut the length of the wearing surface as outlined on one segment, and then reversed and cut from the opposite side for the other segment. The small strip between the two segments should be cut with a pair of hand snips; this will separate the segments and the balance of the strip may be removed by cutting the proper distance from the end of the segment to make the radial portion.

This method has the advantage of giving a straight cut edge which is practically impossible to make with a hacksaw. It will also be noted that there is quite a saving in the amount of mica required by the new method in comparison to the old method of making one at a time. None of the manufacturers of mica plate recommend cutting it with square shears, but my experience has been that the damage done to the segment is negligible.

Cleveland, Ohio C. B. KECK.

New Equipment

for plant operation and maintenance

Industrial plant executives concerned with the selection and operation of mechanical and electrical equipment will be interested in these new devices which are designed to improve plant operation or reduce operating and maintenance costs.

Cast Aluminum Floodlight with Chromium Reflector

CHROMIUM-PLATED reflecting surface, light-weight and airtight construction are the outstanding characteristics claimed for the new cast aluminum floodlight manufactured by the Westinghouse Electric & Manufacturing Co., East Pittsburgh, Pa. This floodlight, it is stated, is particularly well adapted to railroad, roundhouse and industrial plant use. The chromium-plated surface of the reflector, according to the manufacturer, lengthens the life of the reflector and is economical because it eliminates the necessity of delicate care that is essential with other types of surface; it is possible to wipe off dust with gritty waste and still not damage the reflector. The chromium-plated surface has high reflecting properties, will not tarnish or break and is not subject to corrosion from either sulphur fumes or water vapor.

One of the features of this new floodlight is its light weight, with its rugged and sturdy construction. This floodlight is practically airtight and weatherproof and so prevent moisture and dirt from entering. This feature is obtained by sealing the lamp and reflector chamber. In this way the initial efficiency is maintained over long periods of time without any great upkeep costs.

Large Portable Universal Saw

MANUFACTURE of the new, large Wallace Portable Universal Saw has been announced by J. D. Wallace & Co., Chicago, Ill., as the latest addition to this company's line of portable woodworking machines.

This is a portable floor type of universal circular saw that combines advantages of the portable bench machine and the self-contained floor type. The one-way castors make it easy to move from one department of the shop to another. The motor and all working parts are built into the upper portion with the table and fences; thus the top part is a complete, self-contained, bench-type saw when lifted off the regular stand. When it is desired to take the saw out on a job, and it is not convenient to take the regular cast-iron stand, the saw can be taken without its base, and placed on any substantial wooden stand that can be easily made in any shop.

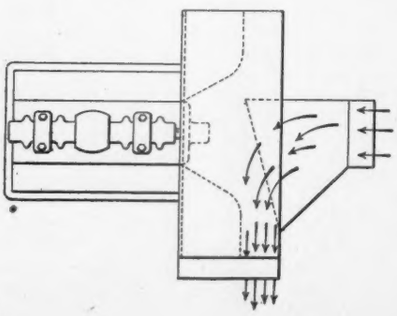
A high-grade, constant-speed, 1-hp., three-phase motor is directly geared to the saw spindle, thus eliminating belts. Ball bearings on the motor are provided with an adjustment for taking up any play. Saw spindle bearings and gears are automatically lubricated by a splash oil system.

This machine, it is stated, is designed to handle small and delicate work accurately, safely and quickly, and yet is rugged and powerful enough to cut rapidly 2¼ in. stock. Utilizing the various adjustments it is also capable of cutting compound miters, grooves ¾ in. wide and 1 in. deep, moldings, groove-and-tongue, and so on, by means of a special dado head. To cut various angles the saw is tilted up to 45 deg., instead of the table, so that the operator is always working on a table that remains in a horizontal position.

Exhaust Fan for Conveying Fine Material

EXHAUST fans of an improved type for conveying finely divided materials by means of air have been placed on the market by the Connecticut Blower Corp., Hartford, Conn. The principal features of the design are shown in the accompanying illustration. Instead of the inlet being placed at the center of the wheel, it is placed near the periphery of the rotor and adjacent to the outlet. A flare in the inlet pipe toward the discharge opening is also provided. The result is that the material conveyed by the air is discharged immediately without being passed through the wheel and around the casing. The purpose of this arrangement is to reduce the wear on the wheel and the housing and clogging or unbalancing of the blades.

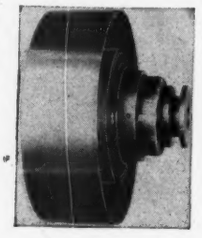
Each wheel contains 16 blades that are riveted to a steel cone and a heavy hub. The air set in motion by the rotor rushes past the projected suction opening and creates a suction therein and simultaneously pushes the material-laden air toward the outlet. The combined effect is sufficient to produce a pressure of 12 in. of water in the discharge pipe, according to the manufacturer.

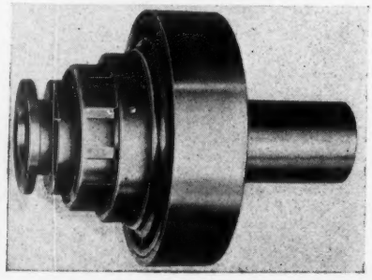


The fans are constructed almost entirely of steel. The belt-driven models are equipped with double-row, self-aligning ball bearings. Direct-connected motor types may also be obtained. The fans are made in 11 sizes, either single or double, with inlet diameters ranging from 9 to 33 in. The smallest single-rotor fan weighs 220 lb.; the largest double-rotor fan weighs 2,200 lb. The fans are reversible and the inlet and discharge connections may be arranged in various positions; also they may be mounted on the floor or bolted to the ceiling. It is stated that the fan will handle any material that can be conveyed by air.

New Disc Clutches

MANUFACTURE of a new disc clutch has been announced by the Edgemont Machine Co., Dayton, Ohio. This clutch, which is known as type E, is of the dry-plate type and is lined with renewable woven-asbestos metallic liners. The clutch is fully enclosed with the exterior completely finished. According to the manufacturer, there is a single adjustment from the outside which is made by loosening a screw in the yoke, turning the adjuster one notch, and then tightening the screw. It is stated that a uniform adjustment is made with the result that the load is evenly distributed. The levers have roller cam contact which makes for easy operation and the elimination of wear. They are so designed, it is said, as to release instantly at all speeds.





This clutch is particularly adapted for machine applications, high-speed operation and on group drives. The new clutch is being made in a complete line of pulleys, extended sleeves and cut-off couplings with slotted cams, or cams for operating through the shaft. The accompanying illustrations show a clutch pulley with cast-iron oil sleeves (above) and a cut-off clutch coupling. These clutches are equipped with Fafnir transmission ball bearings, Hyatt roller bearings and cast-iron and bronze oil sleeves.

Standardized Drum Controllers

NEW, completely standardized lines of drum controllers embodying new features of construction and comprising units for general purpose, crane hoist, or machine tool applications, for either direct or alternating current, have been announced by the General Electric Co., Schenectady, N. Y. In each group several sizes have been provided to cover a wide range in motor ratings; the small sizes are suitable for wall mounting and those for larger motors, for floor mounting.

A number of distinctive advantages are claimed for the new line. One of the particular features is in the mechanical construction, a skeleton type of frame being used. This consists of a cast cap plate and base to which are hot-riveted rectangular steel bars, thus making it unnecessary, it is said for the back of the switch to function as a framework for holding the top and bottom of the switch together. As a result, the switch is accessible from both back and front for the purpose of making adjustments and renewals.

Another feature, said to be particularly valuable in crane service, is the interchangeability of operating handle mechanisms. A vertical operating lever or a spring return mechanism may be substituted for the horizontal lever with which the switch is equipped by using another dial plate.

New style, self-aligning contact fingers are used. By standardizing the renewable copper tips for all switches of the same capacity, renewal stocks will be reduced to a minimum. Where cross-arcing is likely to occur, preventive barriers and blowouts are provided. Auxiliary contact fingers are provided for control circuits to the line protective switch. The arrangement of those circuits is designed to suit the service requirements of the installation.

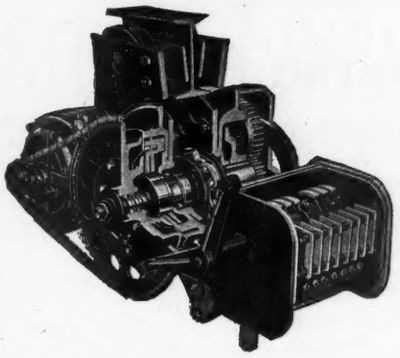
Electric Chain Hoist

ANNOUNCEMENT is made that the Yale & Towne Manufacturing Co., Stamford, Conn., has recently extended its line of electric chain hoists by the addition of the model B-20. This unit is built in capacities of ½ to 2 tons and is designed to provide for close headroom, long lift, higher speeds and greater over-all strength than are found in the former models built by the company.

The suspension member of the hoist, according to the manufacturer, is centralized to give a balanced load on the trolley wheels and hoisting unit, irrespective of the load position. The side plates of the trolley carriage can be spaced to fit the desired beam flange.

The hoist mechanism is inclosed in an oil-tight chamber and is said to be readily accessible for inspection and repairs. The load sheave is carried on large chrome-vanadium steel ball bearings and is bronze-bushed for the driving pinion, which is machined from a single drop forging and heat-treated. All gears, pinions and bearings are splash-lubricated.

Chain containers can be furnished to hold any length of slack chain up to



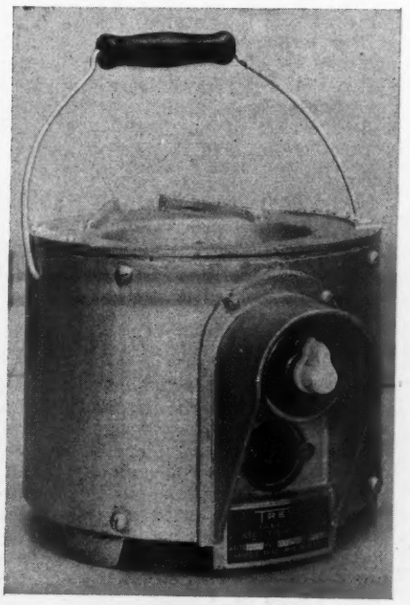
60 ft. for the hoists up to 1-ton capacity, and up to 30 ft. for the 2-ton hoist. These containers are secured to the underframe of the hoist and do not affect the headroom.

Dust-Proof Meter Case

A ONE-PIECE, mahogany-veneered, Micarta, portable meter case has been designed by the Westinghouse Electric and Manufacturing Co., East Pittsburgh, Pa., for standard watt-hour meters. This case is said to be strong, to resist acids and is of dust-proof construction. It is made in one piece with its inner layers of the same Micarta that is used for industrial gears. A tightly fitting, nickel-plated brass ring, lined with felt prevents any dust from entering the box once the meter is inserted. A lid of the same finish as the box protects the meter when it is not in use.

Large Capacity Melting Pot

THE line of melting pots manufactured by Harold E. Trent, 250-251 N. Lawrence St., Philadelphia, Pa., has been extended to include a 45-lb. pot controlled by a three-heat switch and separable plug connection. This pot, which is shown in the accompanying illustration, has been adapted not only for ladle and dipping work, but also for



pouring, as a spout and handle are part of the standard design.

The pot, it is stated, is suitable wherever solder, babbitt, tin or lead is melted, and where rapid, economical heating and sturdy construction are a necessity.

Oil-Filtering Equipment

EQUIPMENT for filtering and removing water from transformer oil or any other oil from which it is important that all water be removed, has been announced by Wm. W. Nugent & Co., 410-412 N. Hermitage Ave., Chicago, Ill. It is stated by the manufacturer that this filter may be cleaned or inspected without stopping the continuous filtering process. For cleaning or inspection the filter bags may be drawn out at the front of the filter, in a manner similar to removing a drawer from a desk. Doors in the front of the cabinet may be opened and the filter bags completely exposed.

Another new type of filter is designed to clean any kind of lubricating or cutting oil that is free from water. It consists of a series of filter-cloth bags suspended from a suitable rack. A steam pipe or electric coil heats the dirty oil as it enters so as to reduce the viscosity and thereby increase the rapidity of the separation of the foreign matter. The filtering process is continuous.

The bags may be quickly removed by raising the cover and lifting the frame off the rack. They should be washed in hot soapy water or kerosene. An automatic bell alarm notifies the operator when the bags require cleaning.

This type of filter is made in 27 sizes ranging in capacity from 40 to 2,000 gal. per hr. and employing from 1 to 40 bags. The filtering surface ranges from 7 to 336 sq.ft. The over-all dimensions for the smallest size, which weighs about 200 lb., are 17 in. by 27½ in. by 46 in.

New Switchboard Fixtures

A NEW line of adjustable supports for wiring installations for permanent or temporary work, and which may be used on timber, masonry, structural steel or pipe framework, has been placed on the market by the General Electric Co., Schenectady, N. Y. The rods, of ⅜-in. cold-rolled steel which may be cut to any length, are used with two forms of supports: the wedge-shaped castings for pipe, or a slotted casting to fit the edge of I-beam flanges. A clamp in the form of an elongated U (a short piece of strap iron turned up at the ends) is used to clamp the rods to the supports. This clamp is also used in clamping apparatus to the rods. The slotted castings for I-beam flanges may also be used on flanges of most of the conventional structural steel shapes. The support is fixed in position by means of a setscrew, which also allows the ready removal of the support at any time. By substituting lagscrews and round spacers in place of the supports the fixture may be used in wooden timbers or planking. Expansion bolts and spacers adapt the fixture to brick, concrete or other masonry.

Trade Literature

you should know about

Copies of literature which is described on this page can be obtained by writing to the manufacturer whose name and address are mentioned. It is always advisable to state the name and number of bulletin or catalog desired, as given in these columns.

Tachometers—Catalog 1120 describes the Frahm vibrating reed tachometer for indicating speeds of 800 to 12,000 r.p.m.—James G. Biddle, 1211-13 Arch St., Philadelphia, Pa.

Oil Circuit Breaker—Circular GEA-62 describes the type FK-32-C oil circuit breaker for 7,500 volts, 1,200 amp., and the type FKR-32-C for 15,000 volts, 600 and 800 amp.—General Electric Co., Schenectady, N. Y.

Inductive Time-Limit Controllers—Publication C-34, third edition, devotes 24 pages to descriptions and numerous illustrations of C-H inductive time-limit controllers in steel mill service.—The Cutler-Hammer Mfg. Co., Milwaukee, Wis.

Gravity Belt Tightener—A circular describes the U.G. automatic belt contactor and other lines of power transmission equipment manufactured by this company.—T. B. Wood's Sons Co., Chambersburg, Pa.

Motor-Driven Pumps and Compressors — Bulletins describe the direct-connected, synchronous motor-driven air compressors and turbine-driven, multi-stage centrifugal pumps.—Pennsylvania Pump & Compressor Co., Easton, Pa.

Leather Belts—A circular gives statements on belt operation from users of Rhoads Tannate and Watershed Tannate belts.—J. E. Rhoads & Sons, 35 N. 6th St., Philadelphia, Pa.

Socket Wrenches — Catalog 326 describes the line of Blackhawk socket wrenches and hand-operated tool grinders.—Blackhawk Mfg. Co., 148 Broadway, Milwaukee, Wis.

Arc Welding—Bulletin 133 describes the lines of Burke variable-voltage and constant-potential arc welders.—Burke Electric Co., Erie, Pa.

Pressure Grease Gun — A circular illustrates and describes the use of Adams grease guns which may be provided with fittings for use with the Alemite, Dot or Zerk systems of high-pressure lubrication.—Adams Grease Gun Corp., 329 Fifth Ave., New York, N. Y.

Resistance Thermometers—Catalog 92 describes the line of Brown resistance thermometers for measuring temperatures from minus 300 deg. F. to plus 1,000 deg. F. and the line of indicating, recording and controlling equipment.—The Brown Instrument Co., Philadelphia, Pa.

Distribution Transformers — Bulletin 2052 describes the Pittsburgh single-phase and polyphase distribution transformers. Bulletin 2053 gives some of the advantages claimed for the Pittsburgh polyphase distribution transformers.—Pittsburgh Transformer Co., Pittsburgh, Pa.

Potheads—Catalog 26 contains 208 pages and illustrates and describes not only the G. & W. equipment but the method of installing this company's line of potheads, underground boxes, distribution specialties, cable terminal devices, insulating compounds and cable splicing material.—G. & W. Electric Specialty Co., 7776-84 Dante Ave., Chicago, Ill.

Panel Boards—Section 4 of Catalog 13 describes a line of panel boards and accessories manufactured by this company.—The Trumbull Electric Mfg. Co., Plainville, Conn.

Conveying Equipment—A folder illustrates and describes the lubricated-gear countershaft box end for Caldwell helicoid and sectional flight screw conveyors.—H. W. Caldwell & Son Co., 1700 S. Western Ave., Chicago, Ill.

Variable-Speed Transmission—Catalog T-66 describes the various sizes and construction of the Reeves variable-speed transmission. A large number of installations are pictured.—Reeves Pulley Co., Columbus, Ind.

Industrial Signals—Visual and audible signals for every industrial purpose are described in the new 16-page booklet entitled, "Benjamin Industrial Signals." Twelve different signaling circuits are shown and numerous other applications described.—The Benjamin Electric Mfg. Co., 120 S. Sangamon St., Chicago, Ill.

Flexible Coupling—Bulletin 103 describes the line of Clark flexible couplings which, it is stated, are fitted together without bolts or screws and do not require oil or grease. It is also stated that they have liberal provision for angular and parallel misalignment and take care of end float.—The Clark Controller Co., 1146 E. 152nd St., Cleveland, Ohio.

Speed Reducers—A catalog describes the complete line of Pittsburgh worm, spur, herringbone and spiral bevel herringbone speed reducers in any ratio for giving straight-line, right-angle, or vertical drives. — Philadelphia Gear Works, Richmond and Tioga Sts., Philadelphia, Pa.

Gears and Speed Reducers—Catalog 200 is a 600-page handbook and contains, in addition to the regular catalog material on gears and IXL speed reducers, a considerable amount of engineering information on this equipment, together with mathematical tables and engineering information on mechanical engineering subjects.—Foote Bros. Gear & Machinery Co., 215 North Curtis St., Chicago, Ill.

Electrical Equipment — Frequently issued, small, pocket-sized catalogs, list and describe the various units of new and rebuilt electrical equipment on hand.—The Fuerst-Friedman Co., 1292 E. 53d St., Cleveland, Ohio.

Conveyors—Catalog 5 of the series entitled, "Wherever Conveying Is Done," is devoted principally to illustrations and descriptions of installations of Brown portable elevators and Standard tiering machines for piling and handling packages.—Standard Conveyor Co., North St. Paul, Minn.

Safeguards—A catalog illustrates and describes a number of safeguards and approved safety equipment for wood and metal-working machinery, belt guards and other safety devices.—The Surty Mfg. Co., Inc., 4127-4139 W. Kinzie St., Chicago, Ill.

Industrial Paint—A circular entitled "More Light" describes the use of Barreled Sunlight in industrial plants. Another circular gives architects' and engineers' specifications for the painting of various interior surfaces with Barreled Sunlight.—U. S. Gutta Percha Paint Co., Providence, R. I.

Choke Coils—Bulletin 117 gives dimensions for both light- and heavy-duty outdoor choke coils. — Electrical Engineers Equipment Co., Chicago, Ill.

Portable Woodworking Machines—Catalog 403 devotes 40 pages to describing and illustrating the line of Wallace portable woodworking machinery for use in maintenance and repair shops, pattern making, cabinet work and other lines.—J. D. Wallace & Co., 134-158 S. California Ave., Chicago, Ill.

Portable Volt-Ammeter — Circular GEA-305 describes the type DS-2 direct-current, portable volt-ammeter which is made in various ranges for general testing purposes.—General Electric Co., Schenectady, N. Y.

Ball-Bearing Pulleys—A circular describes the Pyott ball-bearing loose pulleys.—Pyott Foundry Co., 328 No. Sangamon St., Chicago, Ill.

Oil Circuit Breakers—Special publication 1643-A describes the application of oil circuit breakers, the determination of short-circuit currents, the precautions necessary, and devotes a number of pages to tables and charts.—Westinghouse Electric & Mfg. Co., Pittsburgh, Pa.

Pyrometers—Catalog 15 describes the line of Brown pyrometers for the measurement of high temperatures, illustrates a number of the recording charts used, describes their installation, and gives other valuable information on the use of this equipment.—Brown Instrument Co., Philadelphia, Pa.

Pneumatic Conveying — Bulletin 514 illustrates the use of the Dracco pneumatic conveying system for unloading and conveying soda ash and sand in a large soap manufacturing plant.—The Dust Recovering & Conveying Co., Harvard Ave., and E. 116th St., Cleveland, Ohio.

Time Limit Attachment—Bulletin 530 illustrates and describes the operation of the Roller-Smith direct-acting, time-limit attachment for standard type circuit breakers.—Roller-Smith Co., 233 Broadway, New York, N. Y.